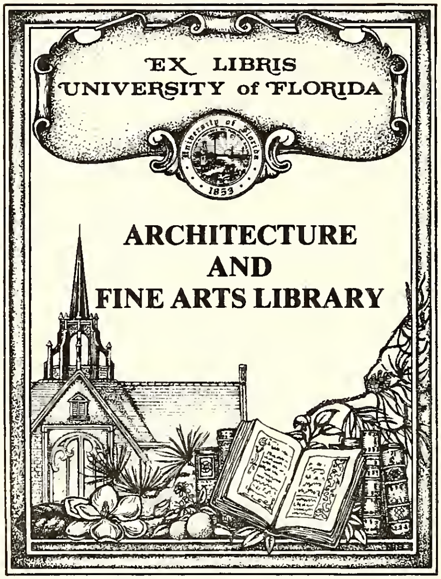

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MATERIALS AND METHODS IN ARCHITECTURE

A compendium of technical articles selected from *Progressive Architecture*

Edited by Burton H. Holmes
Technical Editor, P/A

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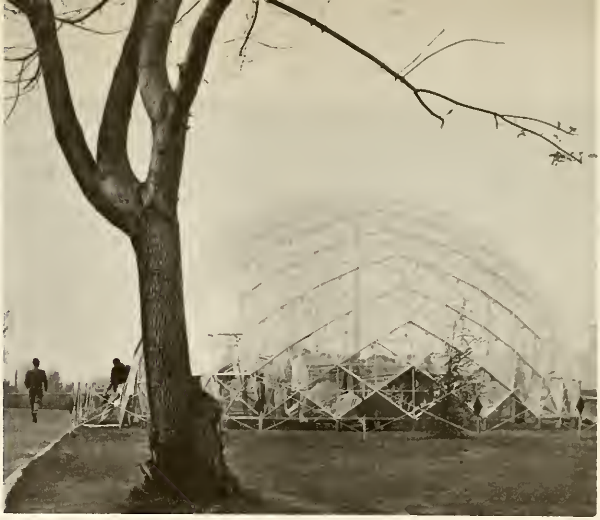
PREFACE

This book does not, by any means, contain a complete gathering of discussions on the art of selecting and designing architectural materials and methods. Such a tome would not only be of unbearable length but also would be impressivley redundant as the great majority of construction techniques evolved over the centuries have been most ably documented and evaluated elsewhere. What this volume does contain, however, is a resumé of many significant developments and improvements in architectural engineering techniques that have been particularly evident during the last five years.

At one time or another, all of the signed articles in this book have been published in Progressive Architecture and were contributed by architects, all types of consulting engineers, and in a few instances by individuals specializing in the research and preparation of technical papers. To them goes the award for whatever value this edition may have for the practicing architect or engineer. It has been the editor's privilege to participate in planning the articles, selecting the authors, editing the manuscripts for production, and finally annotating these pieces and organizing them into a package which it is hoped may be useful—or even of just plain interest—to the practicing professionals following recent developments in architectural engineering techniques.

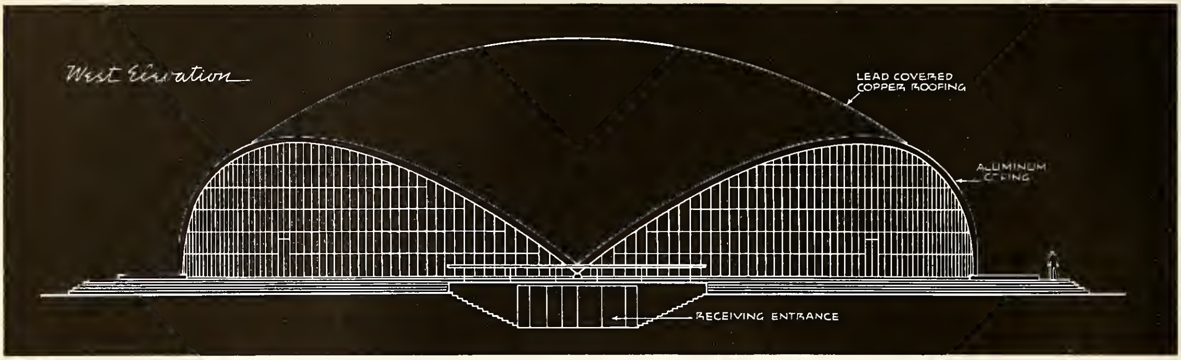
B.H.H.



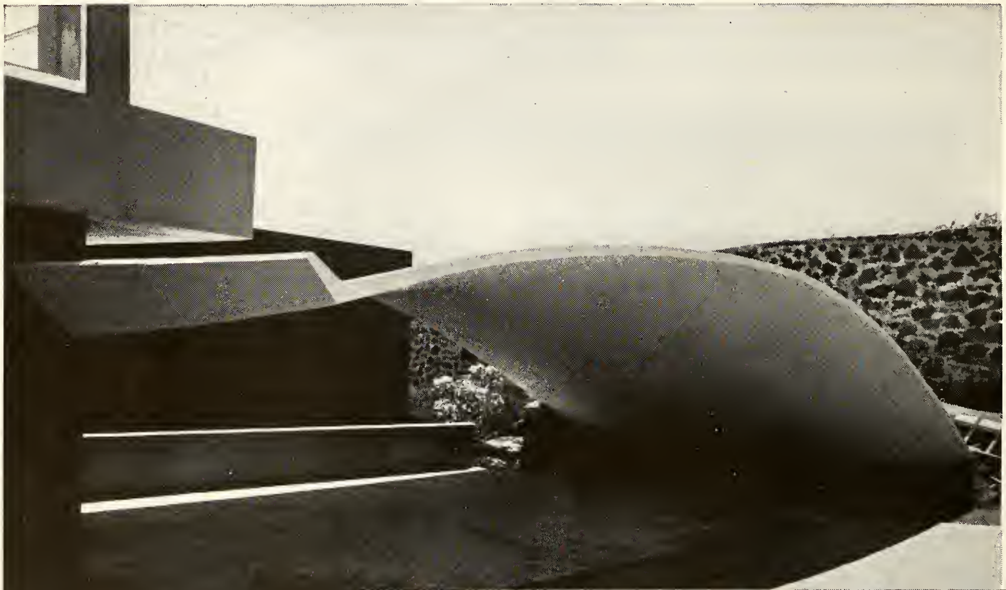
CONSTRUCTION METHODS —TODAY AND TOMORROW

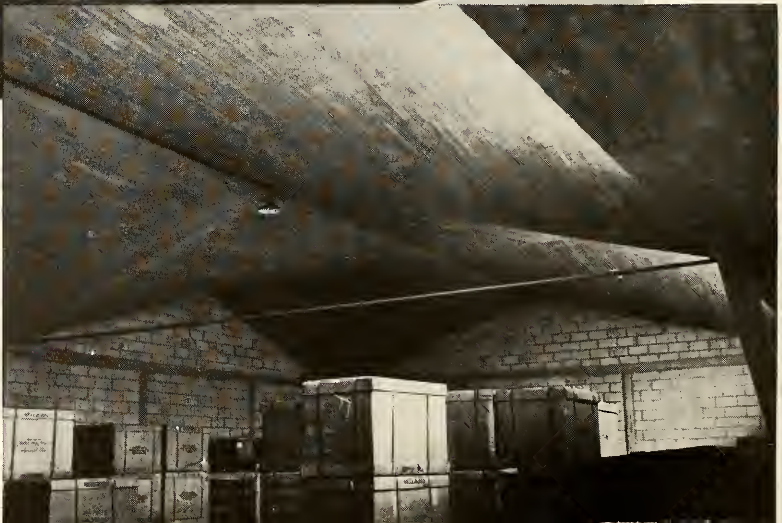
Most of us live a large part of our lives in rectangular cubes of varying proportions and sizes. Structurally, these are generally reticulated boxes placed beside each other or piled atop one another in endless monotony. Paradoxically, the post and lintel system is neither the most economical of material nor the most expressive of form; yet, by far, this method of framing outnumbers all others. To a great degree, this devotion to building with lineal members has been forced upon us by custom, building material production methods that are most suitable for lineal members, and the fact that man's ingenuity has not as yet developed for him other choices that are in a practical sense any more acceptable. There is evidence, however, that we may be in the process of entering a new era of great creative activity in all of the arts and, looking forward to such an epoch, we may anticipate that more suitable, more economical, and less imitative structural concepts will evolve.

On this page, we see a geodesic structural frame, rather modest in size, being erected by students at the University of Oregon (*for additionl discussion of geodesic structures, see page 51*). Extending the possibilities of this method considerably, R. Buckminster Fuller, father of geodesic structures, contends that we possess the technology to enclose similarly the city of Chicago! Yet one must feel that such a system is not appropriate for all types of occupancy nor would such a state of structural design be desirable—even though geodesic construction offers maximum advantages for prefabrication, speed of erection, and lightness of material. Eero



Massachusetts Institute of Technology Auditorium by Eero Saarinen & Associates (above.)





Carport (above) *and Parisina Factory* (right) *by Felix Candela.*

Saarinen, for example, found in his search for the most suitable structural system for the M.I.T. Auditorium that lightness of structure was actually incompatible with the essential purpose of an auditorium—good hearing conditions (*page 2*). Although an average concrete shell thickness of 4½ in. would have been structurally satisfactory for this dome (112 ft radius) spanning 160 ft, it was necessary to surface this sphere segment with a blanket of insulation and an additional layer of concrete in order to minimize exterior noises being transmitted into the auditorium. Felix Candela advances another point of view in his article "Stereo-Structures"* wherein he analytically arrives at the concept that "doubly-curved surfaces are most appropriate from a structural point of view if a material like concrete, molded at the site, is to be utilized." Such a structure has yet to be erected in the United States, but successful ones have been constructed in Europe (notably in Italy by Giorgi Baroni) and in Latin America. Candela's design for the Parisina Factory and a carport for a residence in Mexico City illustrate this concept (*page 2*). Although doubly-curved surfaces are appropriate roof forms, we must recall that we shall probably always have need for multistory structures and that as man has evolved two legs of equal length, he exerts the least energy when walking on level surfaces. Louis I. Kahn and others envision that some form of tetrahedron floor-ceiling system is best suited to integrate the diverse functions required of structure (*page 3 and page 67*). In his Lanificio Gatti factory, Rome, Pier Luigi Nervi, Italian engineer, designed a flat concrete-ceiling with curvilinear ribs strategically poured-in-place to distribute the anticipated loadings (*page 3*).

Although we are denied the knowledge of what lies ahead, it is possible that within this brief cross-section of current structure one may recognize some of the principles that point toward new structural concepts for tomorrow.

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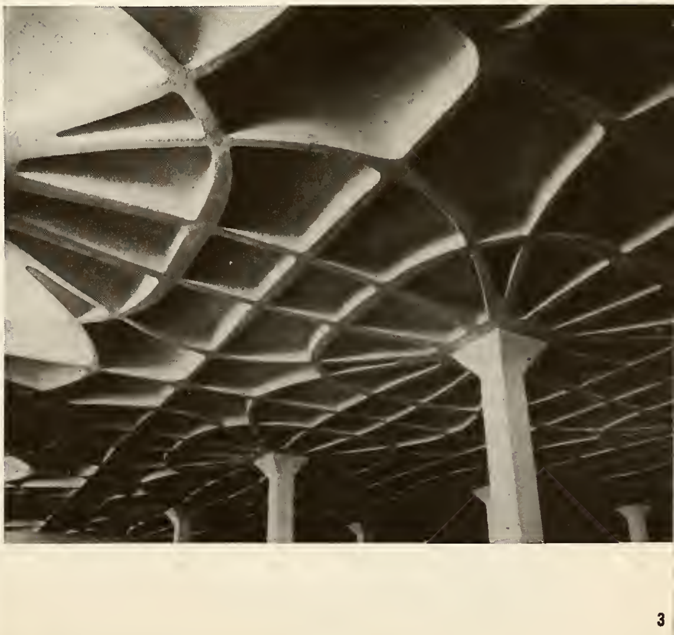
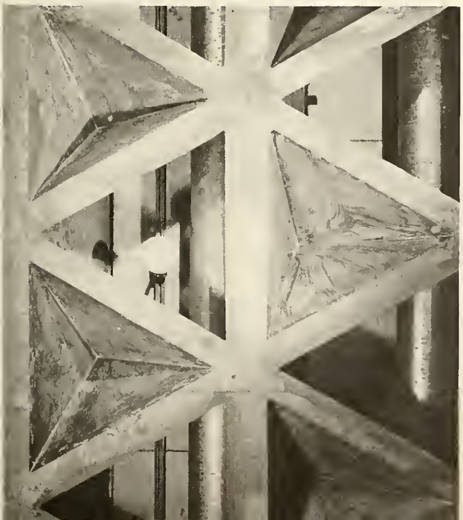
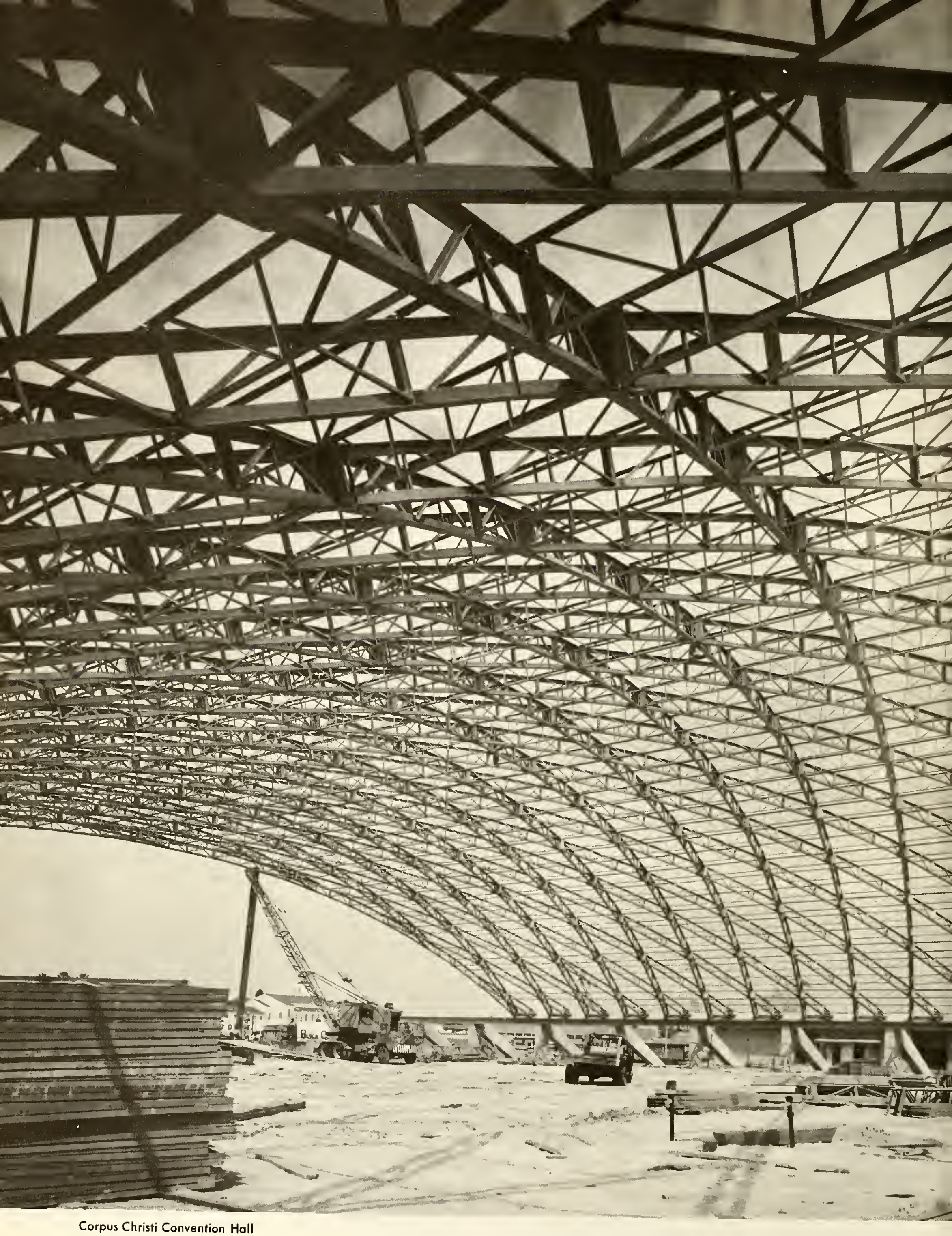
*Progressive Architecture, *June 1954.*

Lanificio Gatti factory by Pier Luigi Nervi (right) *and tetrahedron ceiling by Louis I. Kahn* (below).







Corpus Christi Convention Hall
Architect, Richard S. Colley
Consulting Engineers, Hale & Harvie; G. R. Kiewitt,
Roof Structures Inc.; Blucher & Naismith

THE ROLE OF STEEL

Structural steel permitted Shreve, Lamb & Harmon to carry the Empire State Building to an unprecedented height of 1250 ft in 1931. Twenty-two years later, Mies van der Rohe proposed a square plan Convention Hall for Chicago which, by the use of intersecting structural-steel trusses spaced 20 ft on center, would span 700 ft without interrupting columns! Steel's remarkable property of being equally strong in compression and tension makes possible both of these structures, extremes of verticality and horizontality, and there can be no doubt that in each design the steel is working at the maximum allowable unit stress permitted by the governing building code. Structural steel's exceptionally economical weight-strength ratio is best expressed by the very shapes of the rolled sections themselves; no other lineal building material is more appropriately designed. Without the ability of a material to take tension, cantilever construction, so much a part of contemporary architectural and engineering design, would be impossible. During the last year or so two of the most outstanding cantilevered constructions, from the point of view of length of span, were built of structural steel. A balanced-cantilever system was specified for the recently completed Lockheed hangars at Idlewild Airport, New York. This construction system can provide an area 134 ft deep, of unlimited length, with columns on one side of the structure only—a major advantage for hangars as airplanes can have unobstructed ingress on three sides. The roof is supported by specially designed cantilevered-steel trusses, 20 ft on center, hung from a steel framework extending above the roof surface. It has been reported that hangars of this type can be constructed for $12 per sq ft or less.

Designers of the Boeing Airplane Company hangar at Wichita used double-cantilever construction to provide 195′ x 265′ bays with 55 ft clearances from ground to bottom of steel trusses. Three such bays house twelve B-47's. Advantages and economies in cantilevered-steel construction for more conventional structures are described by Ronald Allwork and Julian Smariga (*pages 16 and 18*).

Curtain Walls of Steel

BY J. G. TERRY*

New concepts of curtain-wall construction have brought the use of steel from galvanized roofing and siding for industrial buildings to the installation of porcelain-enamel spandrels for the General Motors Technical Center (near Detroit) and to the erection of the stainless-steel-concrete panels at Gateway Center (Pittsburgh). Outstanding examples, appearing with increasing frequency, illustrate that steel is one of our most versatile mediums for freedom of architectural expression in the design of contemporary structures.

The use of steel for exterior walls of buildings is not limited to those structures currently being designed; numerous modernization and remodeling programs have made extensive use of the metal façade. Even many of the humble army barracks that were built as temporary structures during World War II have been redesigned so that they can be prefabricated of steel.

For the architect considering steel curtain walls there are many fresh approaches. Various grades of steel that can be used include corrosion-resistant architectural metal of the stainless-steel family and the multi-hued, porcelain-enamel-on-steel finishes. On industrial buildings, special zinc-coated surfaces for immediate painting have taken away the drab look from the factory.

Heretofore the stainless steels have been widely used for building trim. The low maintenance factor of stainless steel has led architects to consider it for prefab wall units to replace brick and other masonry materials. Stainless-steel "bricks" may be as large as 20 to 30 sq ft in size, yet they may be erected in a matter of minutes with decided savings.

Porcelain-enameled steel has long been used as a facing material in order to combine the economy of concrete-block construction with the characteristics of weather-tightness, corrosion resistance, and attractiveness. Although the corner service station and the supermarket have long exploited this material from a standpoint of maintenance and appearance, the designers of the General Motors Technical Center were among the first to advance the architectural use of this material and have integrated it in a monumental building of several stories. In this development, Saarinen, Saarinen & Associates produced a curtain wall with excellent thermal properties, as well as one with a limitless color range.

In the design of steel curtain walls there are several problems that must be considered before selecting the grade of metal. These may be listed as:

1. Wind and weather—selection of a suitable grade to meet wind-loading and atmospheric conditions.
2. Joints and framing—a simple, weather-tight joint and the necessary framework for attaching the panels and transmitting dead and live loads to the building frame.
3. Maintenance factor—selection of a material that will eliminate or reduce maintenance cost.
4. Existing building codes—what is permitted at the building site.
5. Insulation—wet or dry.
6. Vapor.
7. Finish.

The wind-and-weather problem requires that the curtain-wall panel must withstand the attacks of the elements; must maintain a good appearance throughout its useful life; and that it must be designed to transmit the wind loads to the structural frame. Both stainless-steel and porcelain-enameled panels should be satisfactory for the life of a building; however, it has been found that a peculiar problem exists in certain locations where curtain-wall installations are exposed to moisture-laden wind. For example, in the United Nations Secretariat it was discovered that winds driving over the East River forced moisture through normal weep holes and resulted in leakage. Corrective measures required special study and solutions, both in the window area and in the wall itself.

The joint of the steel curtain wall must be designed so that it is weather-tight. Wind-and-rain action must be prevented from driving water through any crevices that may be present in the wall. There are many methods of securing a weather-tight joint—perhaps the best method is a self-flashing joint member. With metal panels, this may be readily accomplished by flanging the joint in such a manner that wind and weather will be excluded.

Provision for expansion must also be made in the joint so that the metal facing will not show the effects of thermal movement. A common method calls for the use of depressed areas in the metal panel; movement will not be noticeable in those areas after the panel is fixed. If the panel "floats" and is calk-bedded, the calking compound may be fractured by movement of the metal panel. Regular expansion joints, at such points as column covers, will have obvious advantages for either floating or fixed panels; the life of the calking compound, nevertheless, is of major concern in any joint system requiring that material.

Closely related to jointing is the way the building is framed. Although there are many different methods of applying the panels, all seem to be fairly well centered in one of three types: (1) horizontal panels between columns; (2) vertical panels, either cantilevered from the floor slab or continuous from floor beam to floor beam; or (3) the grid type, which is a combination of the first two. Selection of the framing method depends on the architect's judgment and the treatment desired for a particular structure. Most panels possess an intrinsic strength that will help to reduce the required framing.

Regardless of the framing system, the

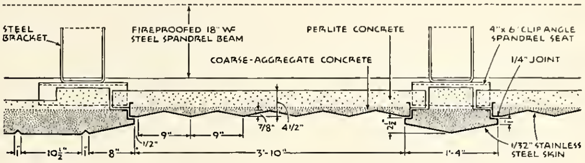
---

* *Development Engineer, Armco Steel Corporation, Middletown, Ohio.*

importance of the maintenance factor cannot be overstressed. First, the material should be a lifetime material; that is to say, one that will last as long as the building itself. All too often, first cost is the only consideration of the owner, and few, if any, buildings are seen as other than a capital expenditure and a maintenance expense. Building accessories are usually purchased on a cost-per-year basis, but this type of accounting is rarely applied to the structure itself. It is strange, indeed, that such a large item as upkeep is not given more thought in the planning stage, and that *cost-per-year*, rather than *first cost*, is not the deciding factor.

Use of steel for curtain walls obviates many of the maintenance expenses ordinarily associated with building upkeep. For example, the stainless-steel pilasters on the Empire State Building and the porcelain-enameled spandrels on the General Motors Technical Center were both designed to require no maintenance. In the 20-odd years since the Empire State Building was erected, the stainless-steel pilasters have never had to be cleaned or maintained in any way. The General Motors spandrels are permanently colored and will retain their bright hues indefinitely. Weigh these distinct advantages against biennial painting, or the repointing of masonry about every decade.

In addition, the self-flashing joints of metal wall panels usually prevent corrosive attack by eliminating leaks in the


STEEL BRACKET
FIREPROOFED 18" WF STEEL SPANDREL BEAM
PERLITE CONCRETE
4"x 6' CLIP ANGLE SPANDREL SEAT
COARSE-AGGREGATE CONCRETE
1/4" JOINT
7/8"
4 1/2"
9"
9"
1/2"
2 1/2"
1"
10 1/2"
1"
8"
3'-10"
1'-4"
1/32" STAINLESS STEEL SKIN

Prefab, stainless-steel-concrete spandrel at Gateway Center being set in heavily calked joints (right). *Detail* (above) *shows relationship of metal skin, coarse-aggregate concrete, and perlite concrete. Architects: Eggers & Higgins and Irwin Clavin.* Photo: Jay-Bee Studio

Porcelain-enamel-faced panels combine weather-tightness with corrosion resistance, as well as satisfy color requirements for the design of the General Motors Technical Center (below). *Individual panel being placed in supporting channels* (below right). *Architects: Saarinen, Saarinen & Associates and Smith, Hinchman & Grylls, Incorporated.*

exterior wall. In a recent survey, an eastern city found that many columns had been severely corroded and had to be replaced. Such a situation not only required huge expenditures but was a safety hazard for personnel using the building in its weakened condition. With proper design, the metal curtain wall eliminates this leakage danger and excessive maintenance cost.

Perhaps the biggest hurdle in the path of steel curtain walls is existing code regulations. Current building codes are based on combustible construction such as wood floors, stairways, and windows plus combustible drapes, floor coverings, and furniture. Requirements for a four-hour fire rating are such that the combustible load must be about 35 pounds per sq ft of floor space. Even in the most crowded filing areas this load is seldom reached; requirements for a two-hour rating are about 15 pounds of combustible material per sq ft of floor area. With today's steel desks and furniture, incombustible drapes and floor coverings, and metal partitions, very few rooms in present buildings even approach the two-hour requirement.

If this is so, are many of today's buildings truly modern? Setback requirements for a contemporary, multi-story building, of course, tend to eliminate the fire hazard from adjoining property. Fortunately, modernization of building codes is now under way in most major cities.

In the selection of insulation for a curtain-wall panel, many types have been considered. Undoubtedly the cheapest method is the use of dead air space, yet this solution increases wall thickness and decreases usable floor area. A balance must be struck between these cost variables.

The type of insulation may be either wet-wall or dry-wall construction. New techniques of pumping plaster and aggregate lower the cost of the conventional wet wall. The dry-wall technique requires assembly near the job site in order to reduce freight charges, and may in some cases create handling and scheduling problems. Dry walls prefabricated with an exterior and interior face pose another problem, namely, openings and variations in structural steel setting. As panels are often prefabricated to tolerances of a few thousandths of an inch, they are not too compatible with structural variations of ½ in. or more throughout the building. The best solution of this problem seems to be in the window surround; errors usually can be discounted in mullion, head, and sill members.

Vapor is a problem in any type of wall. Warm, moisture-bearing air will lose its moisture content on striking a cold surface—regardless of material. Conventional wall materials tend to absorb this moisture and thus seemingly dispose of the problem. However, it must be remembered that when moisture is absorbed by a wall material, the U factor increases greatly. Also, the possibility of structural damage at points where steel members pass through moisture-laden insulation creates a corrosion hazard. The new techniques using metal-foil vapor barriers and mastic coatings are extremely helpful in minimizing this problem in today's curtain wall. There are many impervious materials high in insulating value now available to the architect and contractor.

Finish, both interior and exterior, is an important consideration in the metal-panel wall. With steel, finishes may range from the dull, metallic sheen of stainless steel through the spectrum of colors offered by porcelain enamel. Interior finishes may be metallic or plaster, depending upon the panel types selected. The metallic panel may also be designed for interior location of convector or panel heating.

Let us discuss a few buildings clothed with steel curtain walls that present individual solutions for the various problems previously cited. Although the building types range from monumental to industrial structures, all demonstrate the versatility of steel as well as other valued characteristics inherent in that material.

The General Electric Turbine plant office building at Schenectady, New York *(detail on page 14)*, illustrates the structural-steel conservation possible with steel curtain walls. The structural steel was designed and erected for a conventional construction of three floors. When a planning change required additional floor space, however, the foundations and structure could not take added loads. By the use of cellular, stainless steel curtain-wall panels, a penthouse was permitted on the existing structural members, through reduction of dead weight in the walls.

In Minot, North Dakota, an insulated, ribbed-steel panel was used for the Northern States Power Company Building. Provision for future expansion was of utmost importance and the use of a demountable panel system solved the architect's problem. Expansion may proceed in any direction, and panels will be 100 percent reusable. Interesting architectural effects were obtained by reversing panels in the pilasters. A combination of flush and ribbed areas adds to the vertical effect and is easily achieved. Panel lengths up to 50 ft are standard.

Co-ordinated planning and scheduling by the architects and builders of the Equitable Life office towers in Pittsburgh made it possible to enclose each structure at the rate of one floor per day. The wall is already insulated when installed and requires only bolting and welding for erection *(see illustrations)*. Panels are shop-made, filled with concrete and cured, then set with heavily calked joints. The inside finish (the face of the cast slab) is covered by a continuous air-conditioning enclosure. Important savings were gained in lighter foundation and structural members as well as increased rentable floor space, due to only 4½-in. thickness of the walls.

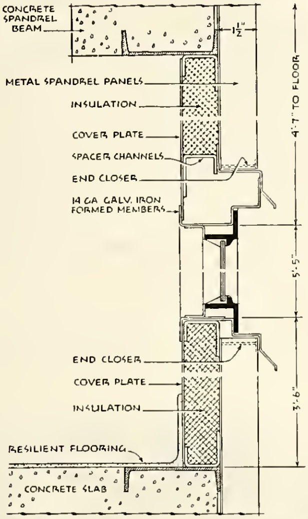
Use of stainless steel goes beyond the actual panels in curtain-wall construction. Buildings like Lever House in New York or the Federal Reserve Building in Detroit utilize the high-strength feature of stainless steel for framing members holding glass and marble curtain walls. The low maintenance feature and freedom from weakening by atmospheric corrosion finds stainless steel ideally adaptable for those important frame members.

While porcelain enamel is a comparatively old architectural material, its use in curtain-wall construction is somewhat new. Probably the most impressive use of this wall material is in the General Motors Technical Center. The double, porcelain-enamel-faced panels float on a calk bed and are placed in channels as shown *(see illustrations)*. Panel insulation can be either calcium silicate tiles, lightweight concrete, or honeycomb paper, depending on the use of the panel for the particular area. A cap channel serves as the stool for the window sill.

In the recent remodeling of the 12-story Security Building in Denver, the porcelain-

The E. F. Hauserman Company plant (neat Cleveland) was originally built with stainless steel panels and measured only 100′ x 250′; an addition of 250′ x 300′ was easily accomplished through the use of demountable panels (right).

Right photo: Robert E. Burke Studios



enamel facing material which replaced approximately 900 tons of brick and terra cotta weighed only 30 tons. Utilizing these panels in the renovation of old buildings offers a solution for the reduction of high construction costs. Further, the metal panels usually reduce the amount of framing needed for hanging and the job proceeds faster.

It is conservatively estimated that there are now about 40 companies in individual research on the various aspects of the curtain wall problem. Some of these systems have already emerged from the research stage, while others are still closely guarded by their developers and have not as yet been offered for any job.

The Porcelain Enamel Institute, whose members are leaders in the porcelain-enameling industry, has retained New York Architect William Lescaze for a full-scale research program to produce a marketable curtain wall. This program is proceeding under the direct supervision of three enameling plant executives who are assisting Lescaze in the important manufacturing phase of the research. Three basic structural systems are being studied, and it may be possible that a total of three solutions will result from the work of this committee.

This undertaking is not purely theoretical research which would require production modifications before manufacture, but is a constructive program based upon a combination of porcelain-enameling knowledge and architectural experience.

Continuous crenellated-steel walls along north and south elevations of Lockheed Aircraft Corporation's new Engineering Building (above). *Compared with conventional 8″ reinforced concrete walls, 800 tons of deadweight were saved. Architects: Welton Becket & Associates.*

Photo: William H. Olson

One of many companies conducting individual research on lightweight curtain-wall panels is the Washington Steel Corporation. Several panels of the type shown (below, left) *are now undergoing thorough testing at their Washington, Pa., plant. Thin, rigidized, stainless-steel skins (Type 302) .015 in. thickness, protect the perlite concrete backing.*

Another curtain-wall material just introduced to the building market by Seaporcel Metals, Incorporated, Long Island City, is a lamination of porcelain-enameled steel to thermal and acoustic insulation materials (below, right).

Type 430 Stainless Steel for Building Panels

BY R. M. STODGELL*

The use of stainless steel for exteriors of insulated panels for buildings has spread rapidly in the years since the war and particularly in recent months. Acceptance of stainless steel for building panel construction—a natural complement to structural-steel framework—has been the result of many influences. And underlying them all is the remarkable success stainless steel has had in the architectural field during the past 25 years.

Basically, the idea of using a panel wall of lightweight material to construct "complete" building walls is not new. The increased interest and growing acceptance of stainless steel in panels has been based on practical necessity. High labor costs combined with many other factors have created a demand for a simple, permanent, virtually maintenance-free building wall material. Because of high land and building costs, the availability of more rentable, or usable interior space—made possible by this type of construction—has attracted many builders.

The use of insulated stainless-steel building panels offers all of the basic advantages inherent in modern curtain-wall design. An architect or builder can think in terms of thin-wall construction weighing only 5 to 8 psf (*Figures 1 and 2*). This results in savings and other economic gains all along the line—in reduced foundations, lighter structural framework, shorter erection time, earlier occupancy, and increased floor area.

In addition, stainless-steel panels are attractive, durable, and at the same time, extremely versatile. They are lightweight and can be installed quickly. They can also be dismantled readily and reused immediately. This versatility of stainless-steel panels, combined with their permanence, has made them attractive to both building owners and metal fabricators.

The use of stainless-steel panels is not restricted to any particular type of structure. This article, however, deals primarily with that large group of buildings, usually with low silhouettes, which includes power houses, laboratories, research and business offices, plant offices, and schools. Stainless-steel panels are also being used extensively for many other types of structures, including multistoried office buildings and large industrial buildings.

Stainless-steel panel construction generally consists of a formed sheet of stainless steel, a layer of insulating material, and a carbon or galvanized-steel backup sheet, the entire assembly usually being from 2″ to 4″ thick (*Figure 1*). Today, fabricators of panels are producing formed sections for modular construction ranging in widths from 12″ to 24″. The length of these panels varies greatly, depending on the design of the building involved.

Formerly, in architectural work, Type 302 stainless steel containing approximately 18 percent chromium and 8 percent

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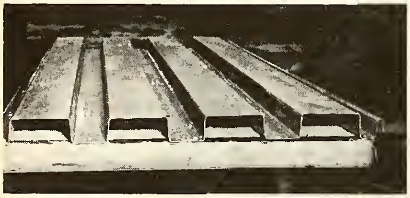
1



Typical panel (left) *has glass-fiber insulation between stainless-steel facing and galvanized-steel back-up sheet. A 14-sq-ft panel* (below left) *weighing but 98 lb can be easily carried by two men. Just before erection, workman calks joint flanges* (below right) *as proper sealing builds up vapor barrier over entire exterior of wall to reduce "U" factor. Two men bolt panel to structural steel at sill, in freezing weather* (right).

2

3

Stainless Steel Division, United States Steel Corporation, Pittsburgh, Pa.

nickel was usually specified. More recently, however, because the National Production Authority has prohibited the use of nickel-bearing stainless steels for curtain walls, architects have turned to Type 430 stainless, containing approximately 17 percent chromium and no nickel for exterior applications.

This straight chromium steel is similar to 18-8 in appearance, possesses adequate mechanical properties, and very effectively resists corrosion. Test corrosion samples of Type 302 and Type 430 exposed for 20 years on U. S. Steel's test rack installations in two separate, highly industrial atmospheres, have remained in excellent condition except for a normal accumulation of surface dirt.

Because of differences in chemical composition, Type 430 is inherently brighter or more reflective than Type 302 in the cold-rolled finishes. But, contrary to a general belief that stainless must always be a highly polished, bright, and reflective

9

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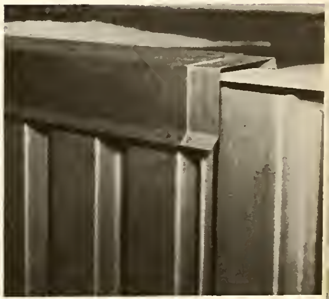


Wing of Technical Center, National Malleable and Steel Castings Company, Cleveland, Ohio (right above): *Dalton & Dalton Associates, Architects-Engineers. Type 430 (20 gage) stainless steel panels, 9000 sq ft total, were formed on a Yoder mill while parapet caps of the same material* (right below) *were formed on a break press.*

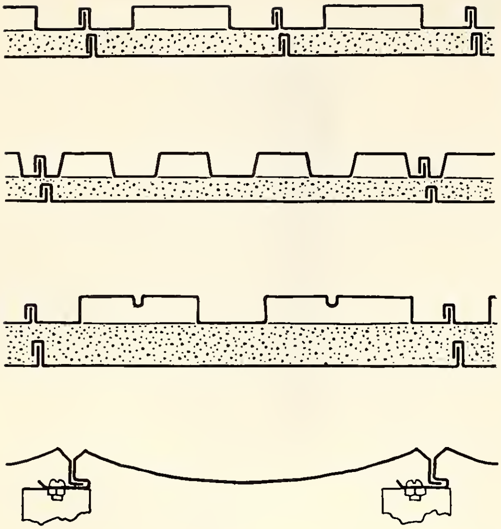
6

7

5

Welding carbon-steel back-up sheet to structural girt of new building (left) *permits quickest method of erection. Three men can easily hoist and place panel in position before bolting or welding to girt* (above left). *Sill flashing, below fixed corrugated-glass windows, is Type 430 (20 gage) stainless steel* (right above).

10



Typical stainless-steel panel sections. Section without insulation (bottom) *was recently used to surface exterior of the existing Heppenstall Building in Pittsburgh.*

material, a stainless finish has a cold-rolled surface which diffuses rather than reflects light falling upon it. It has the approximate density of the standard bright finish and yet it does not possess the "white pickled" appearance of the dull finished product. This finish is obtained by running the stainless-steel sheets through a set of rolls having surfaces that are roughened by grit or shot blasting.

This less-reflective finish requires no special handling or protection. Once in place, it weathers to a uniform dull gray. Type 430 stainless steel, with this special architectural finish, was used for the first time on the three Gateway Center Buildings in Pittsburgh *(detail drawing on page 7)*, and more recently on the new National Malleable and Steel Castings Company's laboratory office building in Cleveland *(Figure 9)*. On each of these buildings there are large areas of stainless steel where anything but a nonreflective surface would be a source of annoyance. This special architectural cold-rolled finish has also been used for four of the buildings at U. S. Steel's new Fairless Works in Morrisville, Pennsylvania. The general office, dispensary, metallurgical laboratory, and fire house are all completely surfaced with Type 430 stainless steel.

Certain design treatments which break up areas of bright reflection may, in some instances, permit the use of brighter finishes on large panels. The use of polished finishes on stainless steel is generally confined to entrance trim, fascias, soffits, and in some instances, to window sash. The Number 4 finish—a polished finish—is usually specified for such applications. But for large wall areas the polished finishes are usually objectionable since they are too reflective and are more costly.

The smooth, dense surface of this steel will, of course, minimize the adherence of airborne dirt, although stainless-steel walls—like any other walls—do require occasional cleaning. How often depends on atmospheric conditions in the area that the building is located. But in any event, the cleaning of stainless-steel walls is relatively simple.

modular panels

One of the important features of a stainless-steel panel is its modular construction which offers advantages from the very outset, from the drawing board where it reduces drafting-room time and simplifies detail, to actual construction, where wall and window erection is simplified. Doors and windows fall into line with modular design which eliminates much of the time lost by making cutouts and adjustments on the job.

The availability of stainless steel in both cut lengths and coils makes it possible to secure a wide range of panel lengths. Panels up to 18′ to 20′ long are readily obtainable and will, in many cases, eliminate the necessity for horizontal joints. Even longer panels can be obtained, if required.

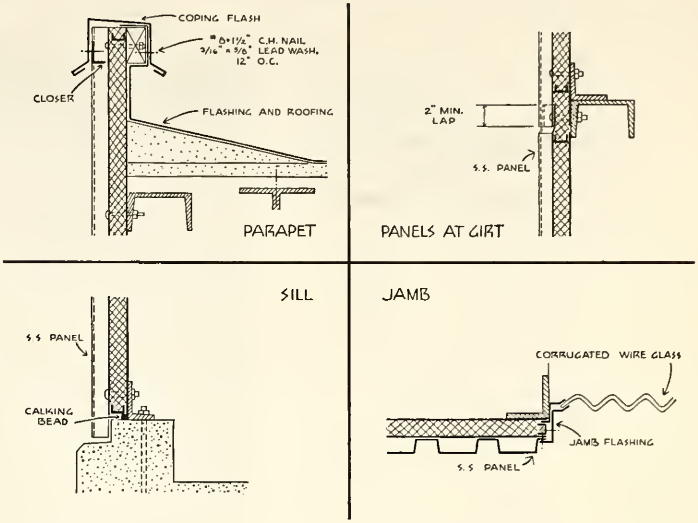
proper design of stainless-steel skin

To keep panel construction competitive with other building methods, stainless-steel fabricators have kept the design of panels simple, yet flexible. Basically, the architect in designing and the panel manufacturer in fabricating stainless-steel panels must keep in mind the relationship between metal thickness and surface treatment. The fabricator's objective is to use a minimum thickness of stainless steel and yet obtain a maximum section modulus—or strength in section. But using stainless steel, a fabricator can consider lighter gages because of the steel's high mechanical properties and superior corrosion resistance.

The experience of several fabricators indicates that when using stainless sheets of 20 or 22 gage, it is important to restrict the width of flat surfaces to no more than four or five inches *(Figure 10)*. Lighter gage sheets should, of course, have even smaller areas of flat surface. Waviness will be evident if light-gage sheets are used for large areas having flat surfaces. Flat surface areas may, of course, be increased proportionately as thicker sheets are used. And by forming sheets in various patterns, flat areas are decreased in size and greater panel rigidity is obtained.

fabrication of type 430 for panels

Fabricating Type 430 stainless steel for a building panel's exterior skin has been accomplished satisfactorily. Stainless steel



11

Recommended structural details for erection of panels. Type A #12 x ¾" stainless-steel screws are fastened 12" o.c.; bolts are ⅜" x 3" stainless-steel round heads, and washers.

for panels of the type discussed in this article has been successfully Yoder Mill formed to a depth of 1½" to 2". Flashing, sills, parapets, and fascia detail are all easily formed on a brake press *(Figure 8)*. However, when using stainless-steel sheets heavier than 18 gage it is important to design fairly generous corner radii into architectural products.

fabrication of panel

Fabrication of a complete panel unit begins with, first, a stainless-steel outer skin (20-22 gage, weighing 1¼ to 1½ psf); second, a 1½" to 2" core of incombustible insulating material; and third, a carbon steel or galvanized steel back-up sheet which completes the wall section and provides a flat, uniform interior surface suitable for painting. Carbon-steel channel stiffeners are usually used to connect exterior and interior panels.

panel joints

Panel joints and laps must be properly sealed. This can be accomplished by the use of male and female flanges at vertical joints and by swaged or die offset and sections to provide flush horizontal joints in the wall. Also, calking is frequently applied to vertical interior and exterior panel joints before erection *(Figure 3)*. Careful sealing not only guards against the possibility of moisture being entrapped at these points but also will help maintain the effective vapor barrier presented by the steel surfaces. In addition, the sealing of joints contributes to the reduction of the over-all heat transmission ("U" factor) of a panel wall. It is advisable, too, to have no through metal-to-metal contact which reduces a panel's insulation value.

insulation

A typical range of over-all "U" factors for a stainless-steel panel wall having 1½" of mineral or glass insulation would be from 0.25 to 0.15 Btu/hr/sq ft/degree F of temperature difference.

erection of panels

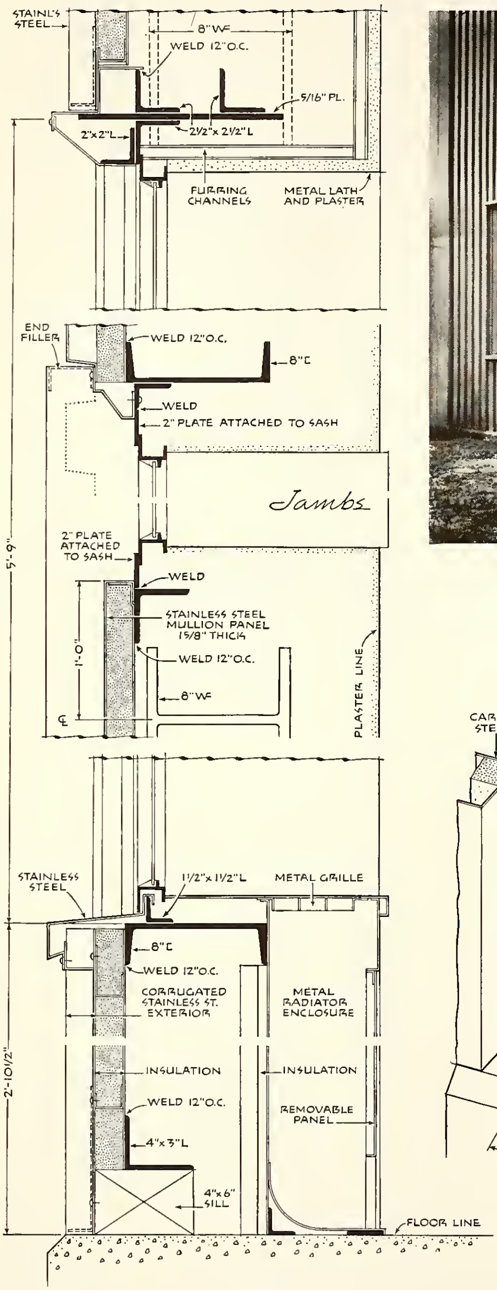
When the stainless-steel panels arrive at a building site, they are ready for erection as soon as they have been removed from the shipping crates. Paper protection for the stainless-steel surfaces, if it has been specified, can be removed and erection crews can quickly drill holes in the four corners of the panels if they are to be bolted to girts. Frequently, panels are tack-welded to the girts. In certain types of insulated panels calking beads are laid in the joints and the panels are then ready to be attached to the structural steel framework. *(Figures 3, 4, 5, 6, 7, and 8 illustrate various steps in the erection of stainless-steel panels; Figure 11 shows typical structural details.)*

During the past year several architects have taken advantage of the adaptability and attractiveness of stainless-steel panels by using them in combination with other building materials. One example is the National Malleable and Steel Castings Company's building mentioned above and another is the Edison Junior High School near Pittsburgh. On both of these buildings Type 430 stainless-steel panels, with architectural finish, have been used in combination with brick. The result has been colorful and attractive, as well as functional. Such material combinations are unlimited and offer the imaginative architect a type of construction which is desirable for many types of offices and institutional buildings.

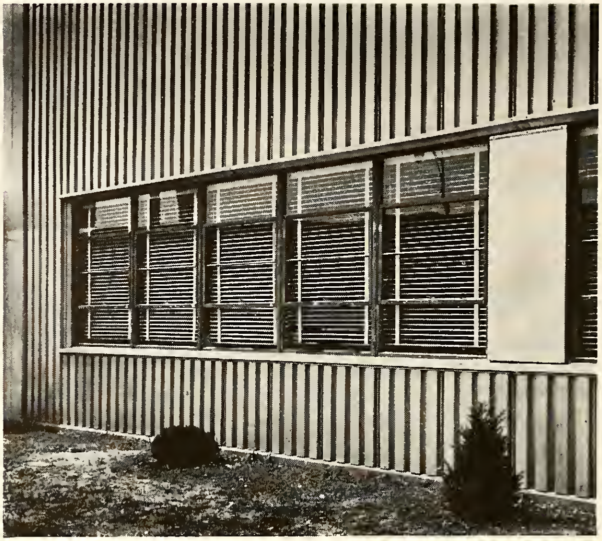
conclusions

Finally, in review, the advantages of Type 430 stainless-steel panel construction include a *reduction in weight*—a possible reduction of wall weight per panel from 100-150 psf of brick-masonry construction to 5-8 psf of stainless-steel panels; *improved insulation*—the coefficient of thermal conductivity ("U" factor) of an insulated stainless-steel panel is approximately 0.15, the equivalent of a 10" masonry cavity wall with 1" of insulation and a plastered interior; *flexibility and versatility*—the original panels can be removed quickly and reused with little or no loss of material; *ease of erection*—experienced crews can erect panels in less than one-third the time required for conventional brick-masonry walls. All these advantages — and many others — have added to the growing popularity of panel construction, using Type 430 stainless steel. This kind of construction is not only attractive—it is economical and practical.

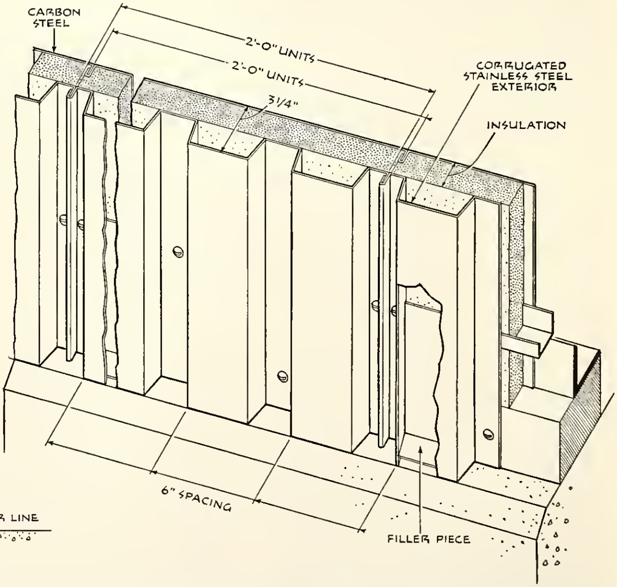
Industrial Building: Curtain Wall



Section thru Wall 1 1/2" SCALE



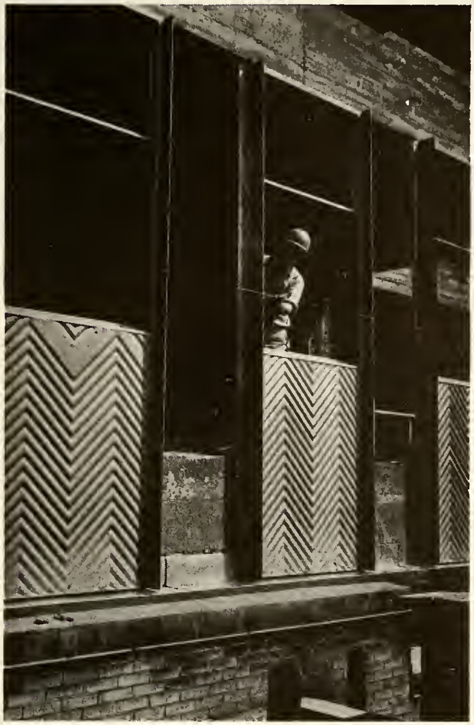
GOTTSCHO-SCHLEISNER



Prefabricated Wall Units

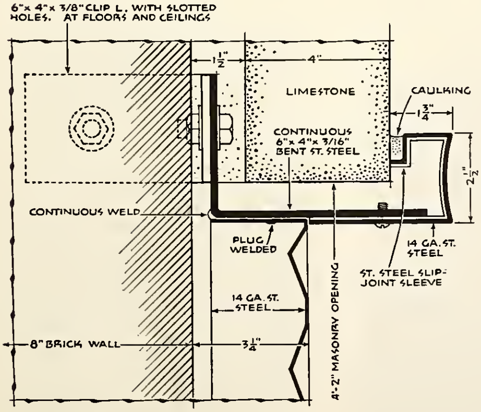
TURBINE BUILDING, GENERAL ELECTRIC COMPANY, Schenectady, N. Y.
Stone & Webster Engineering Corp., Engineers and Contractors.

Commercial Building: Window Spandrel

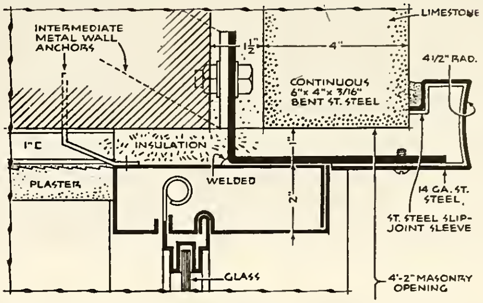


PHOTOGRAPHIC SECTION, U.S. STEEL CORP.

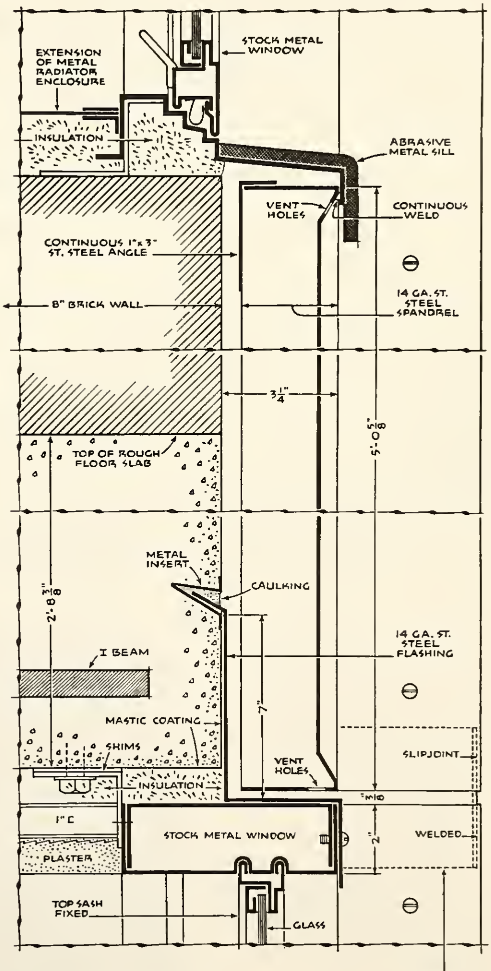
PHOTO BY COURTESY OF THE COMMITTEE OF STAINLESS STEEL PRODUCERS OF THE AMERICAN IRON AND STEEL INSTITUTE.


6"x 4"x 3/8" CLIP L. WITH SLOTTED HOLES. AT FLOORS AND CEILINGS
1½"
4"
LIMESTONE
CAULKING
1¾"
CONTINUOUS 6"x 4"x 3/16" BENT ST. STEEL
2½"
CONTINUOUS WELD
PLUG WELDED
14 GA. ST. STEEL
ST. STEEL SLIP-JOINT SLEEVE
14 GA. ST. STEEL
8" BRICK WALL
3¼"
4'-2" MASONRY OPENING

Plan at Spandrel Jamb 3" SCALE


LIMESTONE
INTERMEDIATE METAL WALL ANCHORS
1½"
4"
4 1/2" RAD.
CONTINUOUS 6"x 4"x 3/16" BENT ST. STEEL
1"C
INSULATION
1"
PLASTER
WELDED
2"
14 GA. ST. STEEL
ST. STEEL SLIP-JOINT SLEEVE
GLASS
4'-2" MASONRY OPENING

Plan at Window Jamb 1/4" SCALE



Spandrel Section 3" SCALE

525 WILLIAM PENN PLACE BUILDING, Pittsburgh, Pa.
W. K. Harrison, M. Abramovitz, W. Y. Cocken, Associate Architects

Cantilevered Steel Construction

BY RONALD ALLWORK*

A framing system for one-story structures based on the use of cantilevered steel members effects substantial savings in steel requirements. An analysis of several industrial buildings designed by Lockwood Greene Engineers, Inc., New York, has shown that the use of this method cuts the weight of steel by approximately 20 percent. A. M. Kinney, Inc., Consulting Engineers and Associated Architects, Cincinnati, have reported that in their design for the White Laboratories building, Kenilworth, New Jersey, the weight of structural steel amounted to only six pounds per square foot *(Figure 1).*

Job records of at least a dozen industrial projects constructed by this method show that the system offers:

(1) Economy in materials and costs.
(2) Less deflection in steel members.
(3) Lower height of building resulting from use of smaller beams and girders.
(4) Ease of erection.

engineering principles are simple

The method is essentially a framing technique in which the girders and beams are designed with a cantilever equal to approximately one-sixth of the span in order to obtain a balance in the positive and negative moments *(Figure 2).* This balance permits the use of lighter steel sections and reduces the weight materially. There are no complex engineering problems to solve. Beam spacing is dictated by the type of decking to be used; bay sizes are developed to meet building use requirements. As in conventional framing, heavy concentrated loads present a problem in the design of individual supporting members, hence the system is best suited for use with uniform loading. When large, concentrated, or moving loads must be taken into account, cantilevered framing does not offer exceptional advantages.

The framing design may be described as a series of bay units, each consisting of four columns supporting two girders cantilevered on each end. These girders in turn support a series of beams, also designed with a cantilevered projection on each end. Since the cantilevered girders and beams project only one-sixth of the span, the remaining two-thirds of the span must be connected by supplementary framing. It is obvious that the girder connection at the column head is relatively simple when compared with conventional framing methods, and that the resulting speed of erection makes an important contribution to savings in construction costs.

In the erection procedure, it is possible for the contractor to use a tractor crane and work progressively down the line of bays without encountering the delays occasioned by the extensive bolting operations required for conventional framing methods.

An important consideration which favors the use of this system is its adaptability to the use of stock and module sized materials. Common steel shapes are employed in the framing and may be either bolted or welded. The beam system can be designed for any one of the many types of precast roof slabs as well as steel or wood decking.

the larger the span, the greater the cost

From the standpoint of architectural

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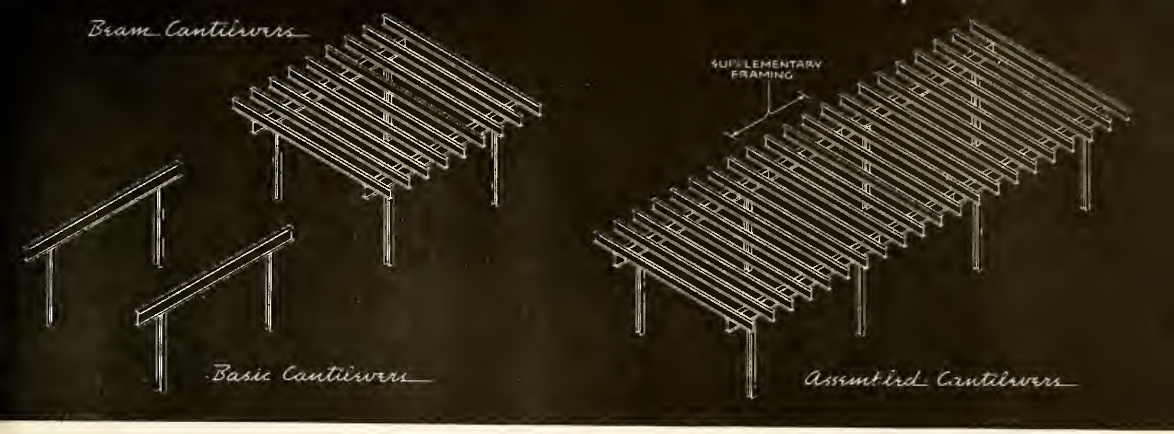
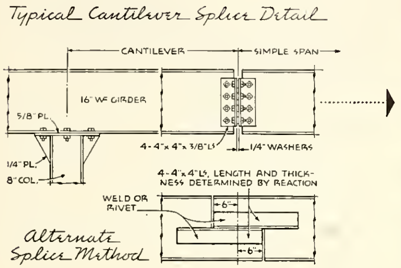
*Architect, New York City.





design, the intended use of the building usually governs the determination of bay sizes. In any type of construction, costs rise as the bay dimensions are increased. With this system, bay dimensions must be developed not only in terms of building use and construction costs, but careful consideration must be given to the maximum length of steel that can be shipped and handled efficiently.

In general, a 20- to 30-foot span for beams appears to be most economical, while column spacing for girders is best at 40 to 45 feet. To effect a real economy, the building should be designed several bay units in width.

Construction procedure requires that two bays of cantilever members must be erected before the short member between can be set in place. While this constitutes the principal deviation from conventional framing, it presents no problem to the contractor and is generally speedier and cheaper.

This method is particularly adapted to use in one-story buildings and all of the known examples have been confined to this height.

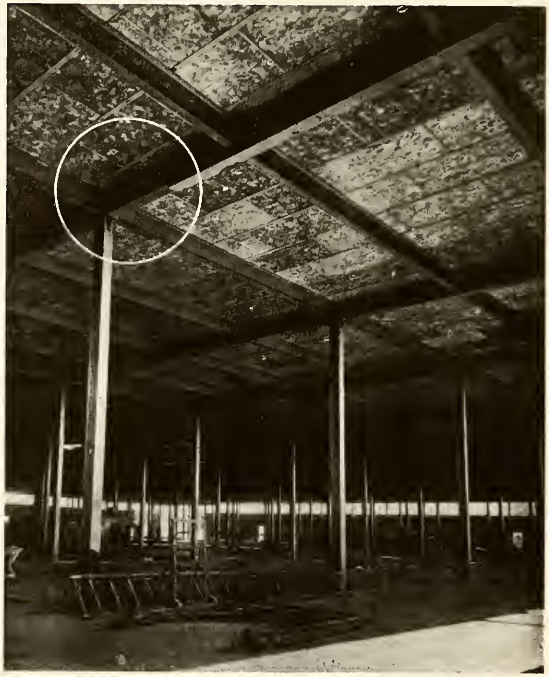


Figure 1—progress photo of White Laboratories plant shows (encircled above) typical cantilever and connection at interior column line of an exterior bay. Cantilever and connection for typical bay (20′ x 30′) are detailed in structural drawings (left). Only the girders are cantilevered in this structure. Underside of glass-fiber form boards between purlins were left exposed, to provide an acoustical ceiling. ***Photo: courtesy Owens-Corning Fiberglas Corp.***

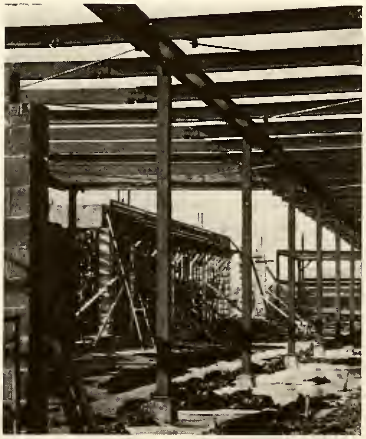


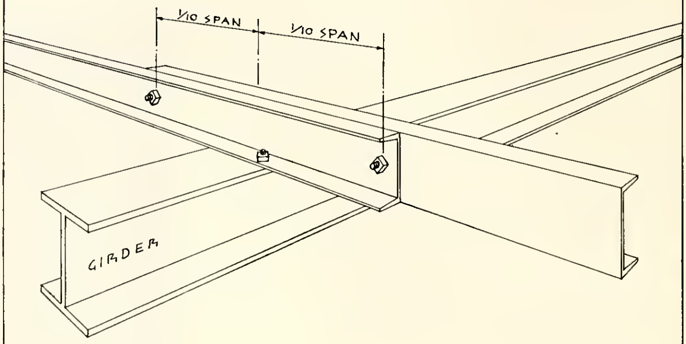
Figure 2—both girders and beams are cantilevered for maximum economy in this building for the Egyptian Lacquer Company.
Photo: courtesy A. M. Kinney, Inc.

Steel Design Economy

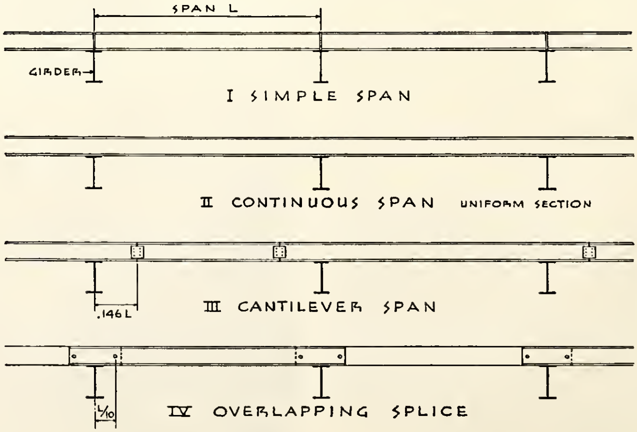
BY JULIAN SMARIGA*

Steel conservation practices are a must factor in building design today. The high standards of design currently used make fairly efficient application of structural material, therefore a great reduction in the total weight of steel-framed buildings is not generally possible. However, an appreciable saving in some elements of framing can be achieved by certain design and construction techniques which have proven economically feasible.

Continuity of framing presents one of the greatest opportunities for using steel effectively. Complete continuity is readily achieved by welding. This method is widely used in those areas of the country blessed with progressive building teams. A modified form of continuity (described as cantilever steel construction) is economically feasible without welding, as demonstrated in several examples.[1] Another way of developing controlled continuity without welding, known as the overlapping-splice method, is illustrated (*Figure 1*). This method achieves substantial weight savings without a corresponding increase in fabrication or erection costs, and has been used in the roof construction of several building types.[2]



DETAIL OF OVERLAPPING SPLICE FIGURE 1



TYPES OF FRAMING FIGURE 2

overlapping-splice construction

The web splice connection of the overlapping-splice method of construction (*Figure 1 shows a typical detail*) should be designed for a shear force of 0.425 wL. For average conditions, this connection will generally require only one or two bolts; for unusual spans and heavier loading conditions, rivet bolts may be used to reduce the number of connecting units required. The proportions of the overlap indicated are designed for uniform loading conditions and, therefore, are generally applicable only for roof construction. Isolated conditions of concentrated loading could be taken care of by strengthening the indi-

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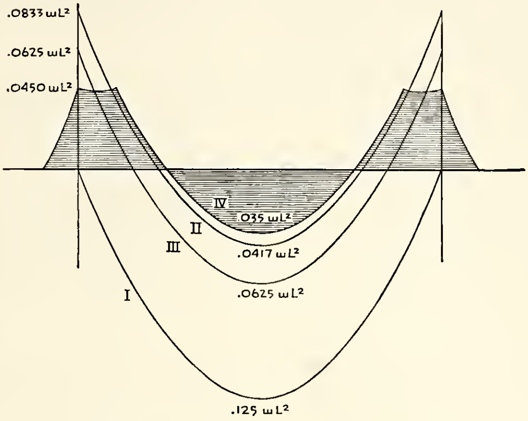
** Structural Engineer, Division of Hospital Facilities, Public Health Service.*

[1] *"Construction Techniques That Conserve Steel," by Ronald Allwork. November 1951 P/A.*

[2] *"Welded Rigid Frame Structures," by A. Amirikian. October 1940* The Welding Journal.



MOMENT DIAGRAMS FIG. 3

Type of framing	Design moment	Comparative section required*	Relative weight factor excluding connections	Maximum deflection	Relative deflection factor
I	$.1250\ wL^2$	10 WF 21	1.00	$\frac{5\ wL^4}{384\ EI}$	1.00
II	$.0833\ wL^2$	8 WF 17	.81	$\frac{wL^4}{384\ EI}$	.38
III	$.0625\ wL^2$	10 [15.3	.73	$\frac{wL^4}{192\ EI}$	.64
IV	$.0450\ wL^2$	8 [11.5	.65	$\frac{wL^4}{542\ EI}$	.47

* Assume that the net section modulus at the critical section is reduced by having one hole punched in each flange.

vidual members involved. It should be noted that fabrication and erection procedures are simplified by the elimination of splice plates and angles.

comparative study

Several commonly used design schemes were selected for comparative study (*Figure 2*). The stress pattern for uniform loading in each scheme is shown (*Figure 3*), where the relative stress economy is clearly evident. It is believed that the overlapping-splice detail provides the best possible balance in positive and negative moments for rolled structural-steel members.

A comparative study of the performance of each design scheme was made and the results tabulated (*left*). An examination of the sections, weights, and deflections will show that the theoretical advantage of design moments for the overlapping splice is reflected in an appreciable weight saving without penalizing the deflection characteristics.

The technique of overlapping is especially suited to purlin or girt sections supporting a surface subjected principally to uniformly distributed loads, such as roof or large wall areas. For main frames and supporting girders, individual design and proportioning is desirable to distribute the required material in an efficient manner.

The comparative summary does not include fabricated joist members, since considerations other than weight economy may enter into the decision to use steel joist construction. However, in comparing the relative weights of steel-joist construction verses overlapping-splice construction, the span length appears to be the controlling feature. It seems that for spans up to about 22 feet, rolled steel with an overlapping-splice detail is more economical in weight of material than bar joists, while for spans over 22 feet long, bar-joist construction will be lighter.

Arc-Welded Beam and Column Framing

BY NED L. ASHTON*

The recent erection of several outstanding all-welded steel frame buildings indicates the rapid advance of arc welding into the construction field. This advance is the result of original thinking and creative engineering by architects, engineers, and fabricators.

Arc-welded construction cannot be economically sound, if its design simply replaces rivets with welds. The problems of welded connections must be analyzed and solved by the application of new ideas.

As the details used in some of these recent structures are outstanding examples of sound engineering practice in welded construction, the principles involved can be studied with profit by all who have an interest in the progress of building engineering. The following paragraphs describe and illustrate the manner in which some heavy beam and column details have been accomplished.

Continuous Interior Girder

Figure 1 shows in trimetric projection a continuous interior wind bracing girder and column connection. This typical detail was used for some of the heavier framing at the third-floor level of the new ten-story addition to the Register and Tribune Building in Des Moines, Iowa. Brooks and Borg were the consulting architects and engineers for this construction. C. A. Jenks, of Chicago, designed this detail for the Pittsburgh Des Moines Steel Company. It shows the junction of two 36 WF 260 girders with the flanges of a 14 WF 426 column, and two 16 WF 40 beams framing into the column web.

In this design, all holes were eliminated from the main columns by fillet and plug welding both erection brackets to the web and erection angles to the flanges. Thus the punching and drilling was confined to small pieces of angles easily handled for welding in the shop. Holes were provided, however, in the ends of the girder webs and in the outstanding legs of the erection angles. These holes were only used for drift pins and bolts in alignment and for temporary support during erection.

Full continuity was obtained at the bottom of the 36 WF girders. This was achieved by field butt welding the bottom flanges of the girder to the column flanges. The girder flanges bear opposite a stiffener that has been shop welded between the column flanges.

At the top of the 36 WF girders, the cover plates and the stiffener plates between the column flanges are shipped loose for convenience in erection. Tie beam erection brackets are provided on the column webs to support the 16 WF beams. The plates between the column flanges are field butt welded to the column flanges after the 16 WF beams have been field welded to these erection brackets.

The outside cover plates are then butt welded to the outside faces of the column flanges and fillet welded to the top of the 36 WF girders to complete the detail.

Typical Wall Column

Figure 2 is a similar sketch of a typical wall column in the same building.

In this detail, only one 36 WF 260 girder is supported by the column, and the heavy field welds are therefore confined to only one flange of the column. The stiffener plates are field welded to the inside flanges and the web of the column, but are not welded to the outside column flange.

Rigidity for Seismic Forces

Another ingenious and well-designed detail of this type, where equal rigidity was provided in both directions for seismic forces, is shown in Figure 3.

This detail is found in the new Los Angeles Times Building. Rowland H. Crawford was the architect and

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* *Professor of Civil Engineering, University of Iowa. Consulting Engineer, The Lincoln Electric Company, Iowa City, Iowa.*

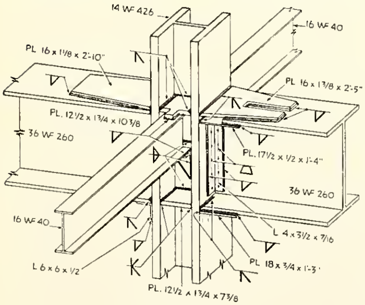

Figure 1.

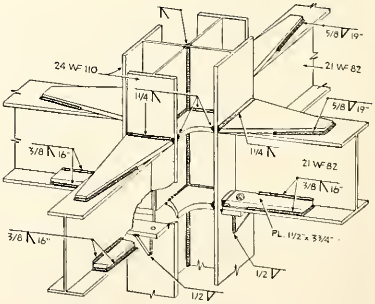

Figure 3.

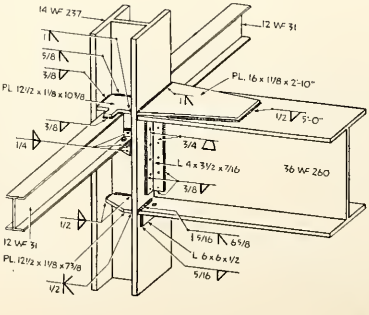

Figure 2.

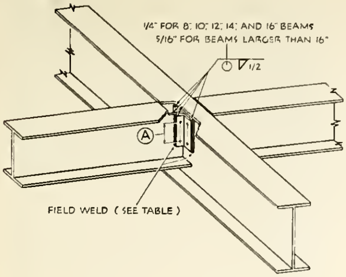
1/4" FOR 8", 10", 12", 14", AND 16" BEAMS
5/16" FOR BEAMS LARGER THAN 16"
1/2
Ⓐ
FIELD WELD (SEE TABLE)

Figure 4.

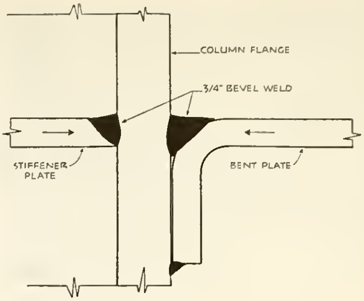

Figure 5A.

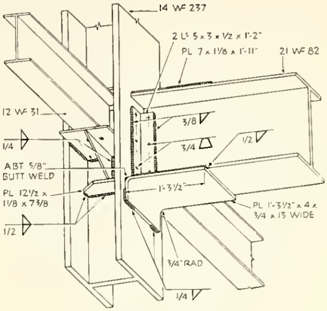

Figure 5, below.

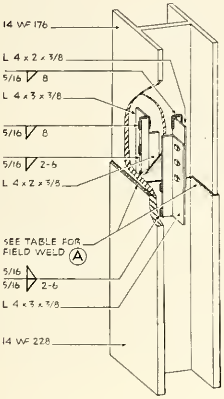

Figure 6.

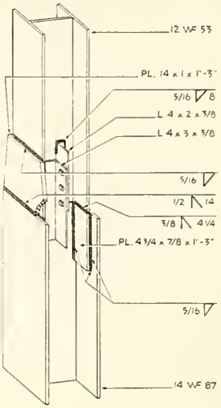

Figure 7.

Holmes & Narver performed the structural, mechanical, and electrical engineering.

In this structure, 21 WF 82 beams were welded to all four flanges of a double 24 WF 110 cross type column. Shop welded plates, 1¼" wide, between the column flanges and opposite the beam flanges, provide full continuity. Tee-shaped bracket beam seats were shop welded to the column flanges and provided ⅞" bolt holes to hold the beam during erection. The 1¼" plates were single bevel welded to the inside of the flanges and to the web to provide diaphragms and back up plates.

Continuity is provided on the outside face of the column at the top of the girder flange by: 1) field butt welding 1¼" top cover plates to the outside face of the column; 2) fillet welding the plates to the top flanges of the beam.

At all bottom flanges full continuity was provided by fillet welding 1½" x 3¾" plates on the top of each bottom flange and on each side of the web.

Beam-to-Beam Connections

Figure 4 illustrates how simple beam-to-beam connections with end connection angles were made with the arc in the Register and Tribune Building addition.

All of the smaller sized beams in this structure were designed as simple beams with two standard connection angles at each end.

In this type of connection, one angle is shop welded to the supporting girder and the other is shipped loose, bolted to the girder. The outstanding legs of both of these angles are punched with a minimum number of holes so that the beam can be temporarily supported until the rest of the connection is welded.

The beam web is also punched at the ends for the erection bolts. In this manner, the beams only have to be cut to length, coped or blocked for erection clearances, and to have the web punched. They are then ready for painting, shipment, and erection. The principal detailing is confined to the main girders and larger pieces. The punched holes and connection angles allow adequate erection clearances, and yet insure exact beam span lengths, correct main girder spacing, and provide excellent support for each individual beam connection. This support is provided without interference, during erection, from the beam connection on the opposite side of the girder.

Table I shows a typical set of standard welded simple beam connections of the type used on the Register and Tribune Building. The table gives the number of bolt holes that were provided for the erection of various sizes of beams, and also the amounts of welding for the permanent connections.

All of the smaller sized beams were designed as simple beams. Flanges were not field welded except for the main wind bracing and continuous girder connections to the columns.

In designing beam or beam-to-girder connections, shop punching of the main members should be eliminated as much as possible. This will materially reduce fabricating costs, as the beams or girders are large and heavy and are costly to handle.

Beam-to-Column Framing

At the wind brackets, the continuity of beam-to-column framing was gained in a unique manner as shown in Figure 5. 15½″ x 4″ x ¾″ bent plate seat angles were shop welded to the column flange with the long leg outstanding. The ¾″ plates were bent to a ¾″ radius on the inside of the bend. Space was provided for about a ¾″ butt weld between the back of the outside radius of the bend and the face of the column flange as shown in Figure 5A. At the same time, the 4″ vertical leg of the bent plate is fillet welded to the column flange to help provide for shear. The rest of the shear is provided for by means of the end connection angles. One of these angles is shop welded to the face of the column with plug and fillet welds while the other is shipped loose and field welded to the column flange and beam web after the beam is erected in the field.

Continuity in the top flange of the wind bracing beam is provided for by means of the 7″ x 1⅛″ cover plate. This plate is shipped loose and then placed in position after the beam is erected. It is butt welded to the column first and then fillet welded to the top flange of the beam.

This connection provides for the bending moment capacity of the beam combined with an end shear of 65,000 pounds. Suitable backing plates are also provided between the column flanges, as necessary, to resist the tension and compression forces without bending the column flanges.

Splices

Figure 6 shows a typical splice also used on the addition to the Register and Tribune Building. The splice shown is the junction of a 14 WF 176 column and a 14 WF 228 column occurring 2′-0″ above the third floor level.

The ends of both of these column sections are first milled for a square bearing surface. The two lower inside erection splice angles are then shop welded on opposite sides of the web of the heavier column section, so that they project beyond the end of the column. The outstanding legs of these angles are provided with holes for erection bolts. These holes match those in the outstanding legs of the two angles that are shop welded to the upper column section.

The flanges on the lower end of the upper column section are V beveled or J grooved for welding, and the field butt splice is completed by filling these spaces with weld metal. The bevels on both flanges are made from the same side to save handling and turning the column during fabrication in the shop and for ease of welding in the field.

Figure 7 exhibits a similar splice wherein a 12 WF 53 column is joined to the top of a 14 WF 87 column with the aid of two flange splice plates. This splice occurs just above the level of the sixth floor.

Two 4¾″ x ⅞″ x 1′-3″ splice plates were first fillet welded to the web and inside faces of the 14 WF column flanges. The plates were then milled with this column. At the same time, one 14″ x 1″ x 1′-3″ cover plate with the lower end prepared for welding was fillet welded to the outside face of the opposite flange of the 12″ column.

In this manner, both flange welds are made accessible from the same side of the column. This is sometimes necessary for welding and convenience of erection, when new steel is erected adjacent to an old structure. The other details, splice angles, field bolts, etc., for this splice are similar to those previously shown in Fig. 6.

The column splice details used for splicing columns of the same depth were also similar to those of Figure 6. Table 2 gives the data for these other typical splices.

In the upper stories of the Register and Tribune addition it was found more economical to splice the columns with direct bearing and anchor bolt

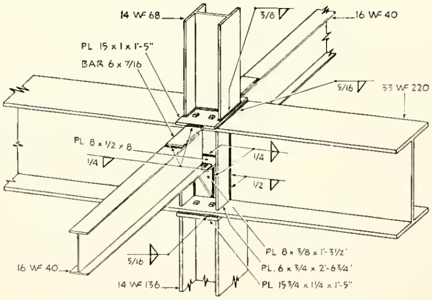

Figure 8.

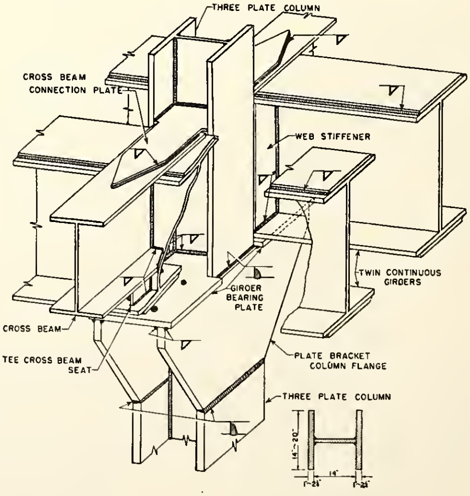

Figure 9.

TABLE 1

beam size	A	field weld	maximum shear (psi)
8" & 10"	No Spaces	1/4" x 0'-5-3/4"	13,800
12" & 14"	1 Space	1/4" x 0'-8-1/2"	25,200
16"	1 Space	1/4" x 0'-11-1/4"	36,700
18"	1 Space	5/16" x 0'-11-1/4"	48,000
21"	2 Spaces	5/16" x 1'-2"	65,000
24"	2 Spaces	5/16" x 1' x 4-3/4"	83,500
27"	2 Spaces	5/16" x 1' x 7-1/2"	101,000
30"	3 Spaces	5/16" x 1' x 10-1/4"	127,000
33"	3 Spaces	5/16" x 2'-1"	144,000
36"	4 Spaces	5/16" x 2'-3-3/4"	161,000

TABLE 2

size of upper column	weld A		capacity one weld
	depth of chamfer	length of weld	
14 W.F 142 to 14 WF 426	1/2"	15-1/2"	113,000#
14 WF 87 to 14 WF 136	3/8"	14-1/2"	80,000#
Cols. with flgs. 12" Wide	3/8"	12"	65,000#
Cols. with flgs. 10" Wide	5/16"	10"	44,000#
Cols. with flgs. 8" Wide	1/4"	8"	27,000#

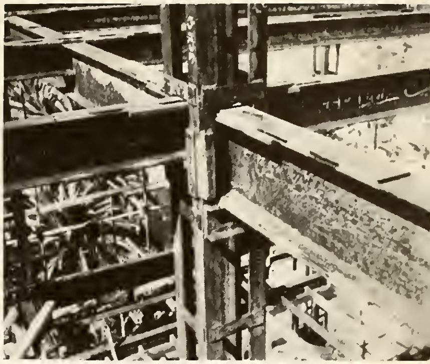

Figure 10.

details, as shown in Figure 8. Bearing on the top and bottom sides of the girder was found more economical than providing a splice at the point of maximum moment in the 33 WF 220 continuous girders.

Thus, milled 6" x ¾" bearing plate stiffeners were welded to the web of the girder between flanges to provide a full bearing support for the upper 14 WF 68 column. The 1¼" cap plates, on the top and bottom ends of the columns, were bolted temporarily, and later permanently welded to the girder flanges.

The cap plates were shop welded to the ends of the column sections. They were permanently field welded to the girder flanges after plumbing and aligning the structure.

Continuity in Both Beam and Column

Another interesting method of providing for continuity in both the beams and the column is shown in Figure 9.

This detail was proposed for the main framework of a large British Nylon Factory of welded construction. This plant is three stories high, 1000 feet long, and 324 feet wide. The floor-to-floor heights were 19 feet for the first story and 13 feet for the second and third.

The column spacing formed 25 foot by 54 foot bays. The columns were formed by shop welding three plates together. Plate brackets were welded into the plane of the column flanges to form integral portions of the column flanges, projecting outward to support the girders. Plate brackets can be made to support loads equal to the load capacity of the column.

The main girders of this structure were made as twin continuous girders supported on the bracketed column flanges. In this manner, the girders may run by both sides of the column without interference. The columns can be completely fabricated in the shop and erected in the field as single units—units three stories high and without field splices. The girders are made to cantilever past the columns with field splices at the points of inflection.

These details saved from 4 to 5 percent of the weight of conventional riveted columns, and about 15 to 20 percent of the weight of the girders. The cost was no higher than the prevailing price per ton for columns and girders of riveted design.

The loads in the individual columns varied from 225 to 765 tons per column. As all columns were fabricated as three plate sections, the plate sizes for the column sections were varied to suit the individual load requirements at each story.

Four Angle Column Section

Figure 10 is similar. In this instance the columns are spread and single web continuous girders run through the four angle column section. This detail, designed by Maurice Sasso, consulting engineer, is found in the extension of the Los Angeles Bell Telephone Building.

The main girders are supported on cross channel batten plates and run directly through the main columns. The four angle column sections are only intended to provide temporary supports during erection. In the final structure, they comprise part of the composite steel and concrete columns.

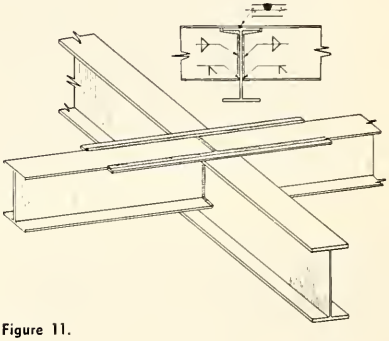

Figure 11.

Continuous Beam-to-Beam Framing

Figure 11 is a sketch of the continuous beam-to-beam framing detail also used in this building. The top flanges of the beams are extended across the top flange of the girder and butt welded together on the center line of the main girder. The additional negative moment flange requirements are made up by cover plates added to the edges of the flanges. The intensity of stress on the butt weld is reduced in proportion to this extra flange material. The web and bottom flanges of the beams are cut to the profile of the main girders. During erection the beams are supported by the top flanges while the webs are being welded to the main girders for shear.

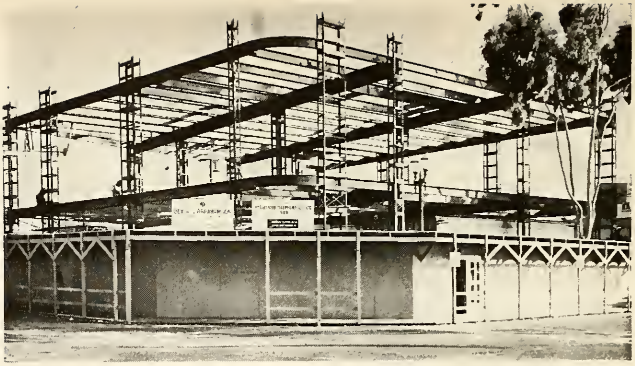

Figure 1, above: completed steel framework of Associated Telephone Company Building, Laguana Beach, California. Designed for welding continuity and rigidity, this framework was erected in 26 hours by six men.

All photos: Ira Carroll: courtesy of The Lincoln Electric Company.

Design for Welded Continuous Steel Framing

BY J. B. McCORMICK*

The people of California have an uncanny ability to make the most of their resources and can even turn disadvantages into assets. Because of slight earth tremors, which in other parts of the world are called earthquakes, their building codes require that all buildings be designed and built to resist dynamic loads resulting from both seismic and wind forces.

Maurice Sasso, a consulting engineer of Los Angeles, has turned the tables on this local peculiarity. He has designed and erected welded continuous steel frames for buildings that not only meet code requirements but also make better and less expensive structures in the bargain.

Sasso recently designed an all-welded steel frame building for the Associated Telephone Company at Laguana Beach. The frame was designed as a riveted structure and also as an all-welded system. From actual bids obtained from the steel fabricator, a total saving in tonnage of 25.7 percent was possible with the all-welded system; the saving in cost of the welded frame over the riveted frame amounted to 18.7 percent in the contract price of the steel frame alone.

Since the riveted frame required girders which were 9″ deeper than the haunched continuous girders used in the all-welded design, the present building would have been 1′-6″ higher in order to meet the client's required clearances, if the riveted frame had been adopted.

The estimated saving in the additional height of walls, ducts, conduits, pipe risers, etc., when added to the saving of the frame alone amounts to 32 percent of the bid price of the welded frame. In other words, it would have cost the owner a total of $8454 more if the riveted frame had been adopted.

The unusual design features contributing to the over-all lower cost of this type of all-welded continuous steel frame are illustrated in Figures 1 through 6, which are photographs taken at the job site of the Laguana Beach Telephone Building.

A unique column structure is the basis for many of the design's advantages. The columns are built-up members consisting of four angles joined together by batten plates, lattice bars, or solid plates. The column is an open crate in section; angles which form the column are spread apart sufficiently to permit the beams and girders to pass through the center of the column without being interrupted at the face of the column. Because of the spread of the angles, the column is capable of resisting larger vertical loads and larger bending movements than an H column of the same cross sectional area. This open crate section, with the beams and girders passing *through the columns,* is the key to the simplicity of attaining continuity and rigidity in the frame and contributes to the over-all economy.

Columns for the Laguana Beach Telephone Building were fabricated in the shop, two stories in length, and trucked to the site for erection. The wall columns were made wider than the square interior columns to provide economically the required resistance to seismic forces.

Figures 2 and 3 show the two types of anchorage used for these columns. The outside wall columns have a split base plate—one plate for each pair of legs. Four bolts bedded in the concrete foundation anchor the column in position. The interior columns rest on solid base plate and are anchored to the concrete foundation by four bolts. The rods seen in these details of the column bases are added

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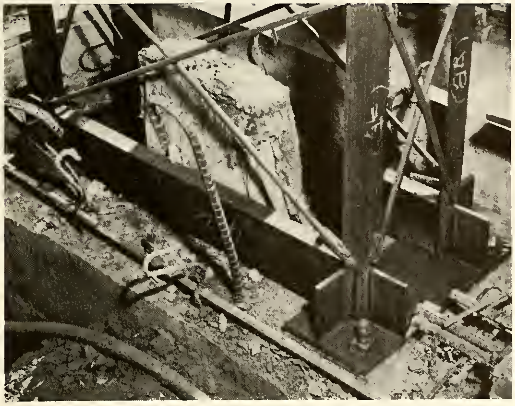
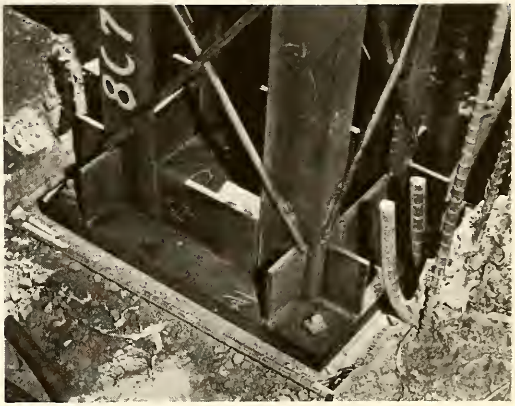
**Welding Engineer, The Lincoln Electric Company, Los Angeles, California.*

Figure 2, below: anchorage for outside wall columns. Split-leg type anchorage eliminates solid base plate.

Figure 3, right: anchorage of interior columns. Bars on columns provide added rigidity in handling and erecting.





during fabrication to give added rigidity during shipping and erection.

Freedom for members to pass through the open crate column section permits the use of multi-span girders. The only limit to the length of girders in this type of design is the practicability of handling on the individual job. In this case two spans are covered with a one-piece girder 60′ in length. The remaining span consists of one 30′ piece which is field spliced to the 60′ member. The 27WF94 girders are reinforced with plates welded on the top and bottom flange across the supporting column extending approximately one-tenth the span length past the face of column. A two span girder weighs approximately 5700 pounds and is erected in a single piece, thus reducing the number of field splices.

The required section for a simple span riveted girder is 36WF160, which is 9″ deeper than the 27WF94 haunched girder used, thereby reducing the height of the present two story construction by 1′-6″, as mentioned before. Note that if a continuous girder of uniform section had been used instead of a haunched girder, the required section would have been a 33WF130, which clearly shows that an additional saving is always realized by using haunched members instead of uniform sections in a continuous frame; this is true for girders and for beams as well.

A single 60′ girder can be erected in total elapsed time of 3½ minutes as proven on this job and on others previously erected.

Figure 4 illustrates how this unusual erection time is made possible. Three men, one on each column (which serve as ladders), simply guide the girder into the column through a door or port which is made in the column during fabrication. Two of the four column legs are cut in the shop and bolted back into place to facilitate handling. When the girder is hoisted into position, the doors in the column are opened, the girder is guided into the columns, then the doors are welded. Once the girder is in place, it is impossible for it to fall out. The bottom flange of the girder is supported on brackets welded to the column.

All beam-to-girder connections are also made fully continuous. The beam-to-spandrel connection is similar in type but not fully continuous and is shown in Figure 5. The top flange of the floor beam is superimposed on top of the spandrel flange.

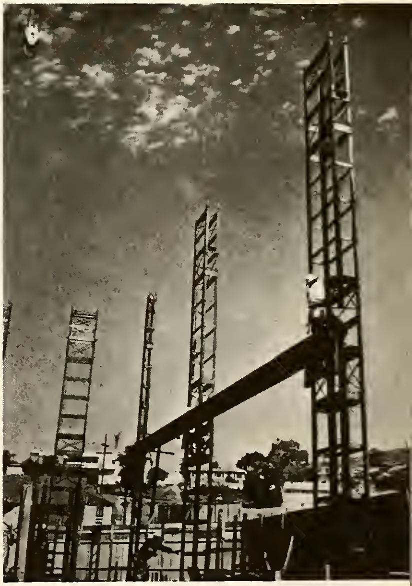


Figure 4, above: one of the 60′ two-span pieces of the main girders being erected. They are raised and inserted into the open crate section columns in 3½ minutes.

Shear connection in the web of the spandrel is made with an angle.

A beam-to-girder connection is shown in Figure 6. The web of the beam is coped so that its top flange will be superimposed on the top flange of the girder. The opposing top flanges of the beams are butt welded and the bottom flanges are welded to the girder web to produce full continuity. The overlaying of the beam flange on the girder flange eliminates the necessity for erection clips and bolts. The shelf angle is used for the shear connection.

Two narrow plates are placed between the top flange of the beam and the top flange of the girder. These plates serve to give an even bearing at this connection which otherwise would be prevented by the ragged edge on the web left in the coping operation. Another cover plate is placed over the top of the joint and also one on the bottom flange. These plates are primarily designed as haunches at the support to reduce the steel section required at midspan. An unbalanced amount of plating between the top and bottom flanges makes it possible for the compression butt weld to work at 20 kips per square inch, while the tension butt weld is working at 16 kips per square inch as required by the local building code.

Due to the interrelation and integration of the columns, girders, and beams at the connections, these members will safely resist any severe or adverse work to which they might be subjected—such as carrying heavier loads than those designed for, dynamic forces due to unusual wind and/or earthquake, repetition and reversal of stresses, etc.

The erection time of this 111 ton job was 26 hours; a six-man crew, including the crane operator, was employed. The erector stated that a comparable riveted frame would have taken about 45 to 50 hours.

From data collected in the construction of five different all-welded steel frame structures, it has been found that this type of frame performs the following savings in the frame alone:

(a) It saves steel because full continuity is developed in the design.

(b) Saves time in shop details and drafting due to the simplicity of the joints.

(c) Saves time in fabrication due to fewer and simpler joint details.

(d) Saves time in erection because fewer pieces are handled; the number of field connections is greatly reduced and their execution considerably facilitated by the simplicity and accessibility of the joints. Because all down-hand welding is employed, all beam-to-girder connections are made without the use of scaffolds.

Quotes from the erector: "with this type of frame twice as much tonnage can be thrown up in a day than with a riveted type frame; the welded joints are completed in 52 percent of the time required for riveted joints."

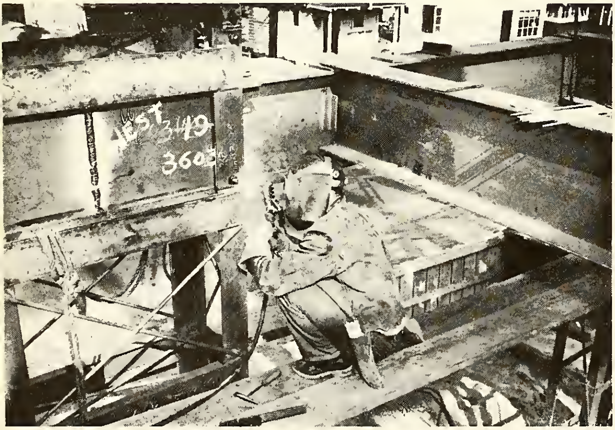
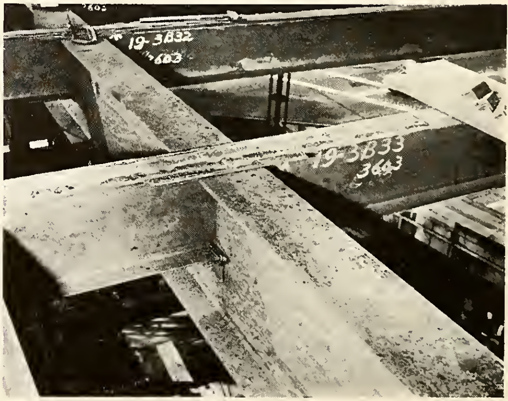


Figure 5, left: erection door in column being shut; this is only place where welding scaffold is required. Detail of beam-to-spandrel connection is shown at right.

Figure 6, below: beam-to-girder connection showing full continuity. Cover plates on top and bottom flange are used to haunch beam at the support.



Pressed-aluminum panels of Alcoa Building (Pittsburgh, 1952) contrasted with church steeple composed of aluminum-alloy castings (1926) demonstrate rapid advance of architectural aluminum.

ALUMINUM-FACED STRUCTURES

Although the use of metals for elements of exterior walls has increased sharply during the last 25 years, the most significant technological advances in metal curtain-wall construction have occurred since World War II. One of the early examples of aluminum curtain-wall construction is found in the A. O. Smith Corporation Science Building, at Milwaukee, designed by Holabird & Root & Burgee in 1928. This structure is enclosed by fixed-glass lights held in an aluminum grillage and, except for its rather dated cornice ornamentation and heavy stone masonry defining the entrance, the building still retains a simplicity that is in harmony with contemporary design currently evolving in this country. As Robert F. Seery points out in the following article on aluminum curtain-wall construction, present practice generally follows one of three curtain-wall systems: prefab panels, facings, and mullion-type construction. Often the choice of method will be limited by the particular building code being enforced in a given locality. Certainly one of the easiest to erect is the panel system designed for the Simms Building at Albuquerque by Flatow & Moore (*page 31*). Used in conjunction with cantilevered, reinforced-concrete construction, vertically placed 5 in. I-beams support the mullions, sash, and prefab panels. Containing 1½ in. glass fiber insulation within the panel itself, this wall is ideally suited for either northern or southern climes. Obviously, when combined with double-glazed windows, as was done in the Simms Building, optimum conditions for efficient and economical air conditioning are present. That aluminum, as a building material for multi-story structures, has captured the imagination of architectural designers in the United States, there can be no doubt. During 1953 more than 70 major projects using exterior aluminum facing were either erected, being constructed, or on the drawing boards. Undoubtedly, there is still much to be learned in the design of aluminum curtain walls; there is no reason to think, however, that improved solutions are not forthcoming. One familiar, disturbing feature has been the waviness in some early structures using facings as the curtain-wall material. Improper gage and welding techniques may have been contributing causes.

Aluminum Curtain-Wall Construction

BY R. F. SEERY*

Curtain-wall construction today demands a more functional design and lower cost than ever before. The problem is to build a light nonloadbearing wall to protect the building interior from the elements of weather and provide a safe enclosure for the occupancy with regard to its location.

Many architects have been extremely successful in achieving new expression for the building façade while providing new methods to solve this basic problem. Architects, builders, and suppliers have all contributed to these developments. The large market gained by aluminum in the building industry in recent years has evidenced its usefulness. Curtain-wall construction is now looked upon as one of the most promising uses for aluminum; its natural advantages and low cost make this possible.

The intent of this article is to present information about materials and methods for aluminum curtain walls. Code or fire regulations are not discussed, but the designer will be given the basic information from which aluminum designing should begin.

advantages

Aluminum has important natural advantages that are present in every aluminum alloy. Its weight, only one-third that of steel, allows larger single sections to be fabricated and erected, thus effecting economies in construction not possible with other materials. Larger fabricated sections mean fewer joints and less possibility of leaky walls.

Weather-resistant aluminum has proven itself for architectural and structural applications. Its affinity for oxygen and natural build-up of a colorless protective surface coating assure this desirable characteristic. Electrochemical processes of anodic finishing provide a thicker protective coating, thereby increasing the inherent corrosion resistance and providing a tougher finish.

The appearance of aluminum can be altered to provide many desirable finishes. The surface can be etched, wire-brushed, or polished, and an additional anodic coating can be applied. For years, castings were the only form of aluminum to present a slate-gray weather appearance. Now, slate-gray finishes are available as extrusions in silicon alloys and as sheet in clad materials. This development has opened new possibilities for aluminum on the building façade, by providing contrasting surface finishes.

Aluminum's workability assures easy forming and fabrication into finished products. Additional economies are effected due to the lower labor cost. There are many instances in architectural design where experience has shown that it costs the same or less to do a job with aluminum, although material costs may be higher. The excellent workability of aluminum holds manufacturing costs down so that the finished cost is lower.

material and alloys

The many alloys and temper designations of aluminum have led to some confusion in the building industry. The numbering system for wrought-aluminum alloys is broken into two parts—for example, the designation 3S-H14. The symbol 3S designates the alloy, while the symbol H14 designates the temper.

The first series of numbers is a guide to the major alloying ingredient *(Table I)*. There may be as many as five other alloying elements in some of these alloys, but these groupings form a convenient system of classification.

The second number designates one of the two temper types. The *non*heat-treatable types, designated by H, are given increased strength by cold working. The heat-treatable type, designated by T, gains in strength by heating and quenching. Each alloy will show its type by the temper designation following its alloy number, unless it has been fully annealed and designated by O; 3S-H14, for example, is a nonheat-treatable manganese alloy and 14S-T6 a heat-treatable copper alloy. The numbers following H and T indicate the degree of temper obtained during processing and the method by which that temper was achieved.

When designing curtain walls, there are three forms of aluminum from which planning should start. They are sheet, extrusions, and castings.

Sheet

Plain, embossed, or clad sheet is available in many sizes and alloys. For the most part, aluminum sheet can be confined to 3S alloy. This manganese alloy is work-hardened to temper and has excellent mechanical properties. 3S has good corrosion resistance and it can take severe bending operations during forming. 3S alloy sheet may also be obtained clad with 43S or 44S alloys. This clad material is used when a special finish is desired. When higher mechanical properties are desired, 52S alloy is recommended *(Table II).*

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*Architectural and Construction Market, Reynolds Metals Company, Louisville, Ky.

Extrusions

These have few restrictions and a great variety of expressions can be achieved with proper planning. Die costs are low. Sizes are normally limited to shapes whose cross sections can be inscribed within a 12-in. circle. As larger presses become available, this diameter will be increased. This size limit can sometimes be increased by a novel method: certain extruded shapes can be extruded as a folded shape meeting the limitations of the 12-in. inscribed circle. The folded shape can then be flattened to provide the desired shape.

Extruded shapes in 63S alloy are best suited for architectural applications. High mechanical properties can be obtained by heat treating 63S, and costs are relatively low. When a slate-gray finish is desired, the extrusion alloy 43S should be used. Strength characteristics similar to structural steel are available with 61S alloy in the T6 temper. 61S-T6 is an economical structural alloy to attain higher properties and maintain high corrosion resistance for structural purposes, but the finish differs from 63S *(Table III).*

Castings

Castings are used when a three-dimensional surface design or a rough-textured material is desired. Casting alloy designations do not follow the numbering system used for the wrought alloys. The letter S is omitted. For general purposes, 43 alloy, an aluminum silicon casting alloy, is used. If an anodic finish is desired and the casting must match a 63S alloy extrusion, then 214 alloy should be used. Castings requiring strength higher than 43 should use 356, which is also an aluminum silicon alloy of the heat-treatable type *(Table IV).*

methods

The designers' choice of curtain-wall sections will depend largely upon the job the wall must perform. A consideration of fenestration and fire safety must first be concluded. From a construction standpoint, aluminum curtain walls can be classified as prefabricated, facings, or mullion types. Each particular type has its design and functional limitations which must be weighed during planning.

Prefab Panels

These wall panels are composed of an exterior facing and an interior facing, usually with insulation in between. The panel is received completely finished and need only be attached to the structural frame of the building to make the installation. Good standard aluminum designs are merchandised by several manufacturers including Detroit Steel Products, H. H. Robertson, R. C. Mahon, Seaporcel Metals, Steelcraft, and U. S. Plywood. If special design considerations are involved, custom-built units can be obtained from aluminum fabricators and installed on the same basis. Although most prefab panels are constructed from sheet materials, they need not be limited to sheet. Extrusions or castings can be prefabricated in much the same manner.

Architects Ervin & Berne, Denver, Colorado, have incorporated custom prefab aluminum spandrels in their design for the Denver Club Building *(Figure 1).* These

Table I: Wrought-Aluminum Alloys

Ranges	Principal alloying constituent	Examples
2S	commercially pure alum.	2S
3- 9S	manganese	3S
10-29S	copper	14S
30-49S	silicon	43S
50-69S	magnesium	63S
70-79S	zinc	75S

Table II: Mechanical Properties Comparison for Sheet Aluminum

Alloy	Yield strength
3S-H14	20,000 psi
52S-H14	31,000 psi

Table III: Mechanical Properties Comparison for Aluminum Extrusions

Alloy	Yield strength
61S-T6	40,000 psi
63S-T6	30,000 psi

Table IV: Mechanical Properties Comparison for Aluminum Sand Castings

Alloy	Yield strength
43	9,000 psi
214	12,000 psi
356-T6 (Heat-treatable)	24,000 psi

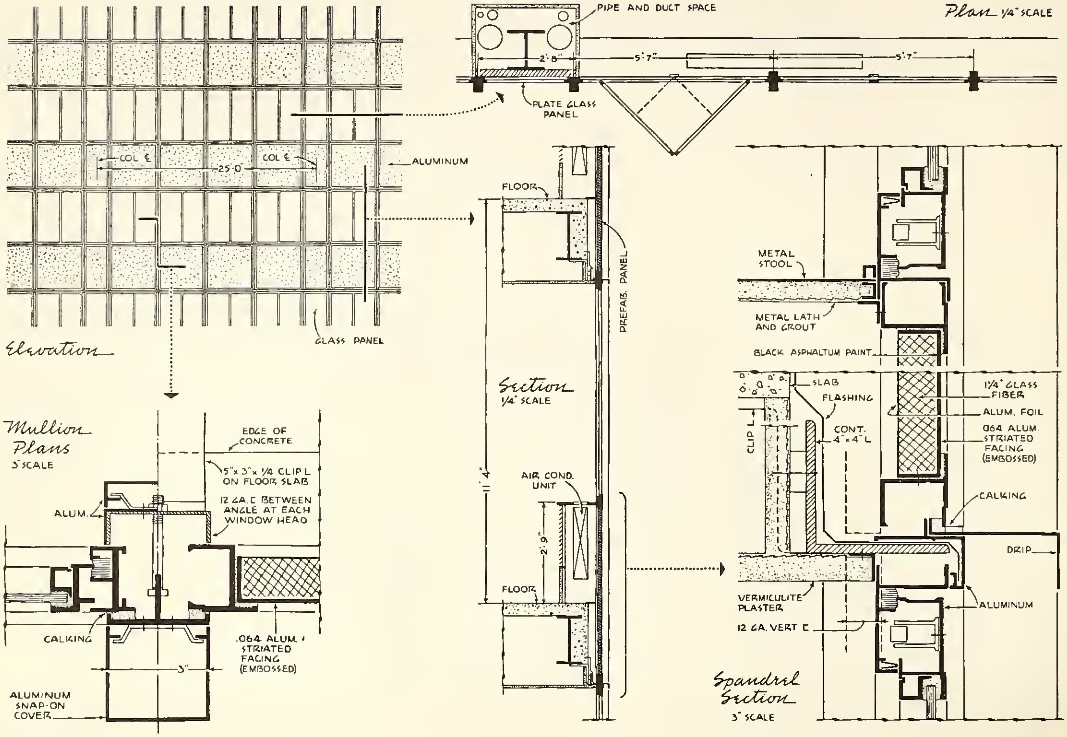


Figure 1—details of aluminum prefab panel construction in the Denver Club Building, Denver, Colo.: Ervin & Berne, Architects.

spandrels, which have a U factor of 0.12, are composed of striated, embossed-aluminum sheet laminated to a glass-fiber insulation backing; the sheet will be treated to provide a satin finish. Flue-type windows containing heat-absorbent glass are made of anodized aluminum. This wall will be erected by the use of clip angles attached to brackets welded to the structural steel frame; each sash with its spandrel below will be placed as a unit.

The Simms Building, designed by Architects Flatow & Moore, Albuquerque, New Mexico, is framed in reinforced concrete and the floor slabs are cantilevered four feet beyond the exterior columns *(Figure 2)*. Spandrels and sash are held in place by 5 I 10 beams bolted vertically to the concrete floor slab at five foot intervals *(see details)*. The spandrels are prefabricated and consist of factory-glazed aluminum-sheet facing with an integral glass-fiber insulation back-up. Vertically-pivoted window units have been specified.

Facings

Sometimes called skin-type spandrels, these facings are classified as those which fasten to or form a part of an adjacent curtain-wall construction. This spandrel type has usually performed a decorative function; however, recent developments in this type classify it as a weather-resisting surface. Facing materials can be any one of the three forms of aluminum previously mentioned; each has been used. Some structures employ these basic forms in combinations to achieve a contrasting effect.

Aluminum castings, long a standard

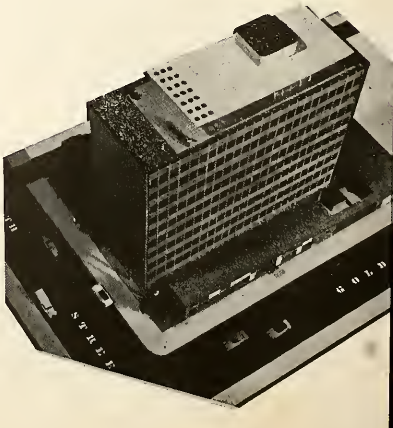
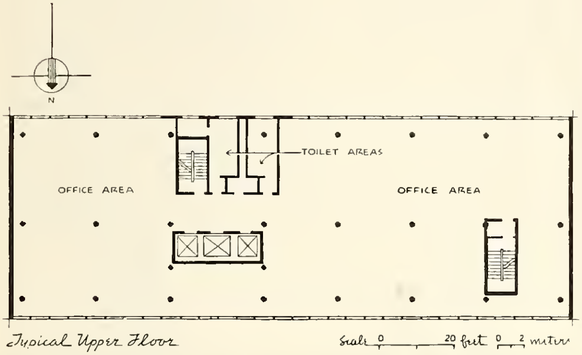
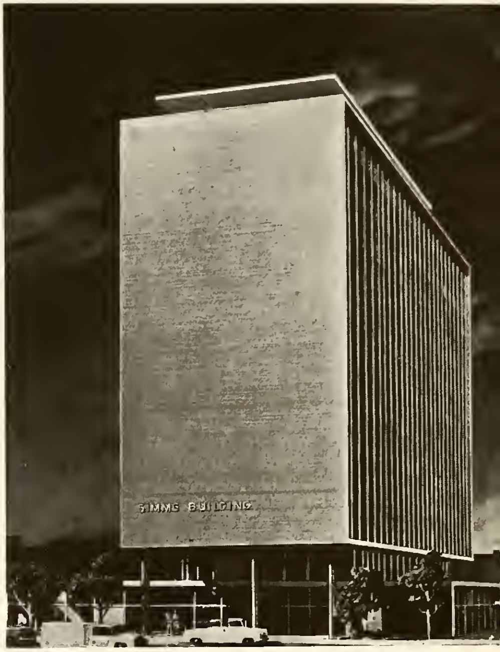
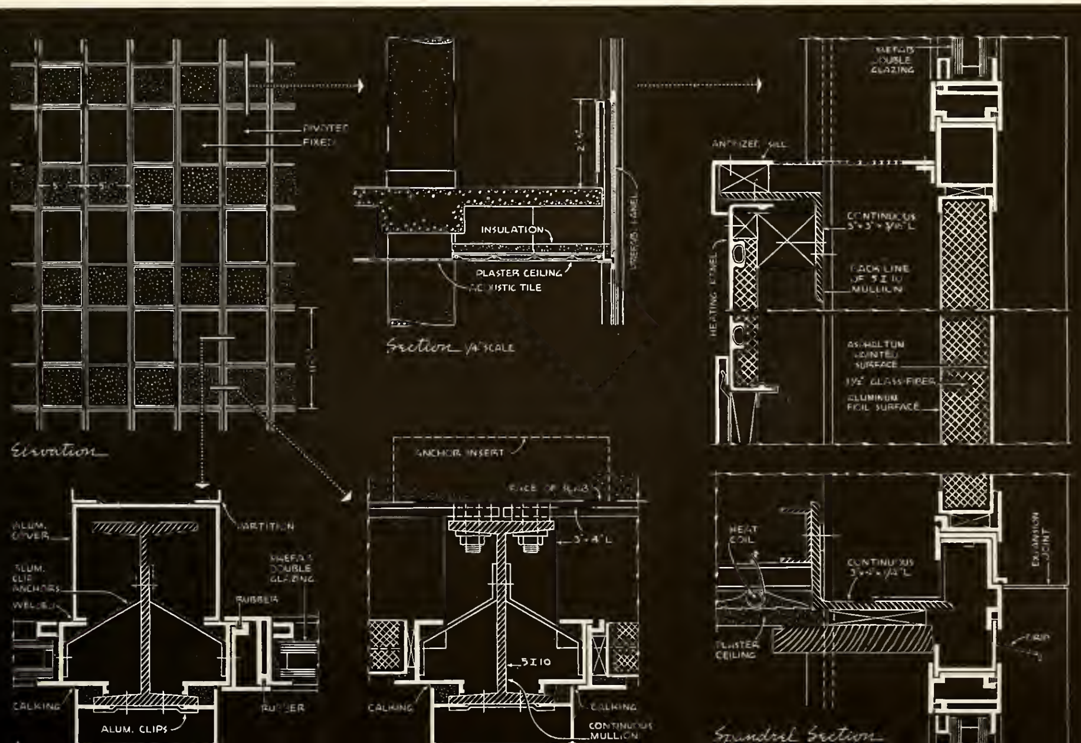


Figure 2—model of the Simms Building, Albuquerque, N. Mex. (right and acrosspage below): *Flatow & Moore, Architects. Typical floor plan and details of aluminum prefab panel construction* (below).







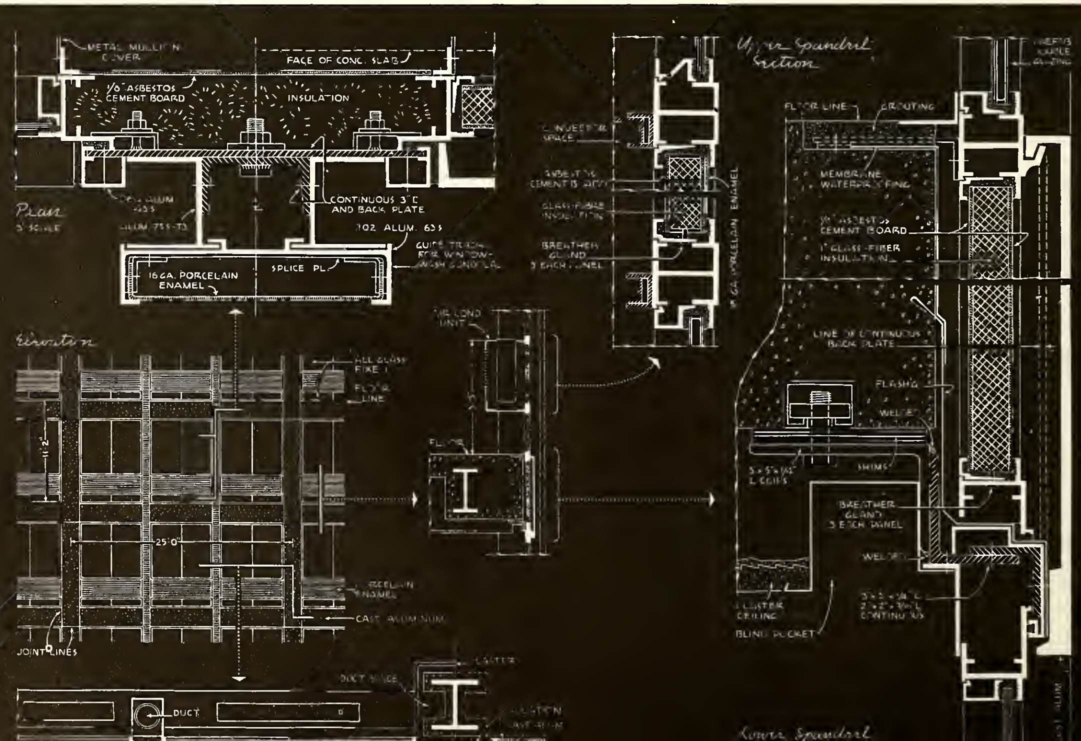
spandrel material, are being incorporated by Webb & Knapp, Inc., New York, in their design for the 1700 Broadway Building in Denver, Colorado. The cast-aluminum facings protect spandrels, columns, and act as guide rails for window washing equipment *(Figure 3)*. Insulated, structural porcelain-enamel panels on the exterior wall support elements of the peripheral air-conditioning system which is encased 12″ above the floor level. Behind the aluminum spandrel facings insulated asbestos-cement panels will be installed.

Skin-type panels have been employed by Emery Roth & Sons, New York Architects, in their design for the 99 Park Avenue Building now nearing completion in New York *(Figure 4)*. Approximately 1800 die-pressed wall and window panels were bolted to the building's framework in 6½ days. Although the 10-gage panels are one-story high, they were welded together at the window heads to form two-story lengths. Extruded members between panels extend the full two-story length. As at the Alcoa Building in Pittsburgh (August 1952 P/A) the prefab panels were installed from the inside so that outside scaffolding was eliminated.

Mullion-Type Construction

On the UN Secretariat Building, New York, for which Wallace K. Harrison was Director of Planning, aluminum extrusions were used as facings for the structural-steel mullions *(Figure 5)*. These extrusions were designed in three pieces—one on each side of the double-channel mullions and a facing piece. Side pieces have a natural finish while the facing piece has a con-

Figure 3—details of aluminum castings for the 1700 Broadway Building, Denver, Colo.: Webb & Knapp, Inc., Architects.



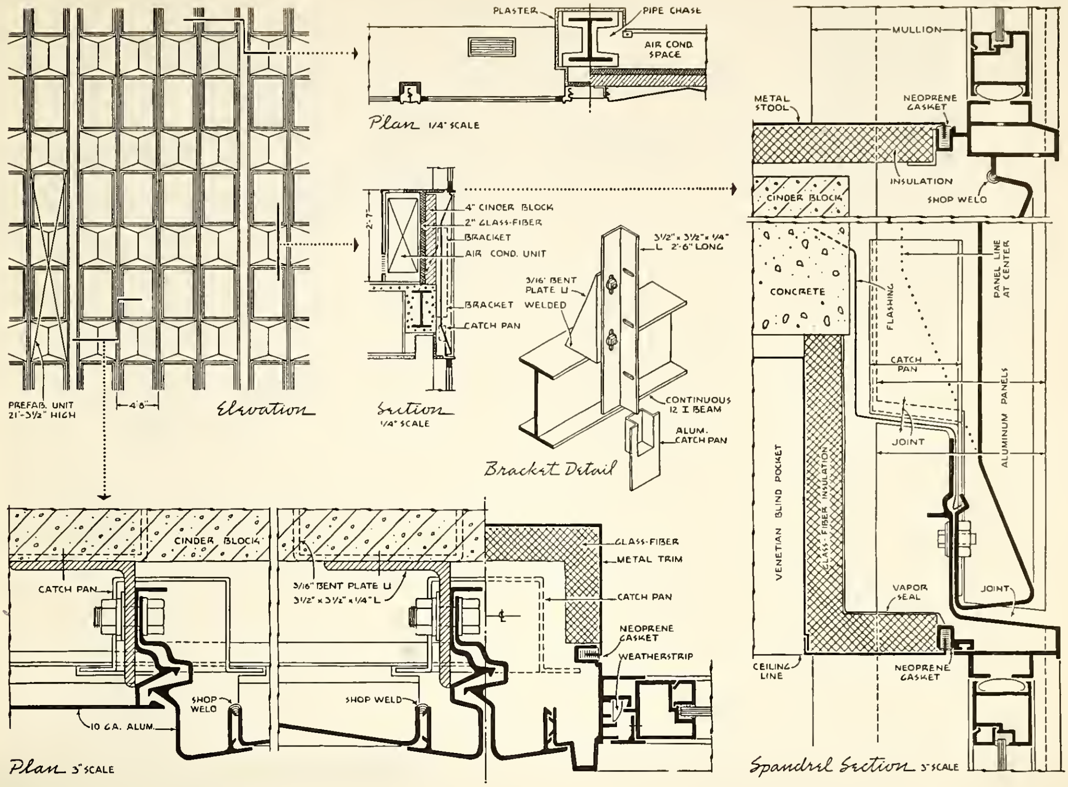


Figure 4—details of aluminum skin-type panels for the 99 Park Avenue Building, New York: Emery Roth & Sons, Architects; Tishman Realty and Construction Co., Inc: owners and builders.

trasting dark finish. Where sides and facing meet, continuous aluminum angles were subsequently needed as corrective measures to make the structure weatherproof; expansion joint covers were also required.

Aluminum fins for the El Paso Natural Gas Building, El Paso, Texas, designed by Carroll & Daeuble, will be constructed of both sheet and extrusions *(Figure 6)*. The sides of the fins will be formed of sheet and the facing will be an extrusion with a dark finish. Spandrels used on this job will also be a combination of formed embossed sheet and matching extrusions.

finishes

Special finishes can be employed to enhance aluminum curtain walls. When finishes are used for this construction, they can be classified as mill, mechanical, chemical, electrolytic, or organic. Many other finishes for special applications can also be applied to aluminum surfaces.

Mill finish is the term used to describe sheet, extrusions, or structurals as received from the mill. A great amount of mill-finish metal is used for curtain walls because natural weathering tends to gray the metal to a uniform surface without special treatment.

Mechanical finishes—grinding, scratch brushing, or polishing—are used to change the surface appearance. Grinding is used principally for removing surface variations from castings. The operation is usually accomplished by means of a rotary grinder but is not in general use for decorative purposes.

Scratch brushing, polishing, or chemical

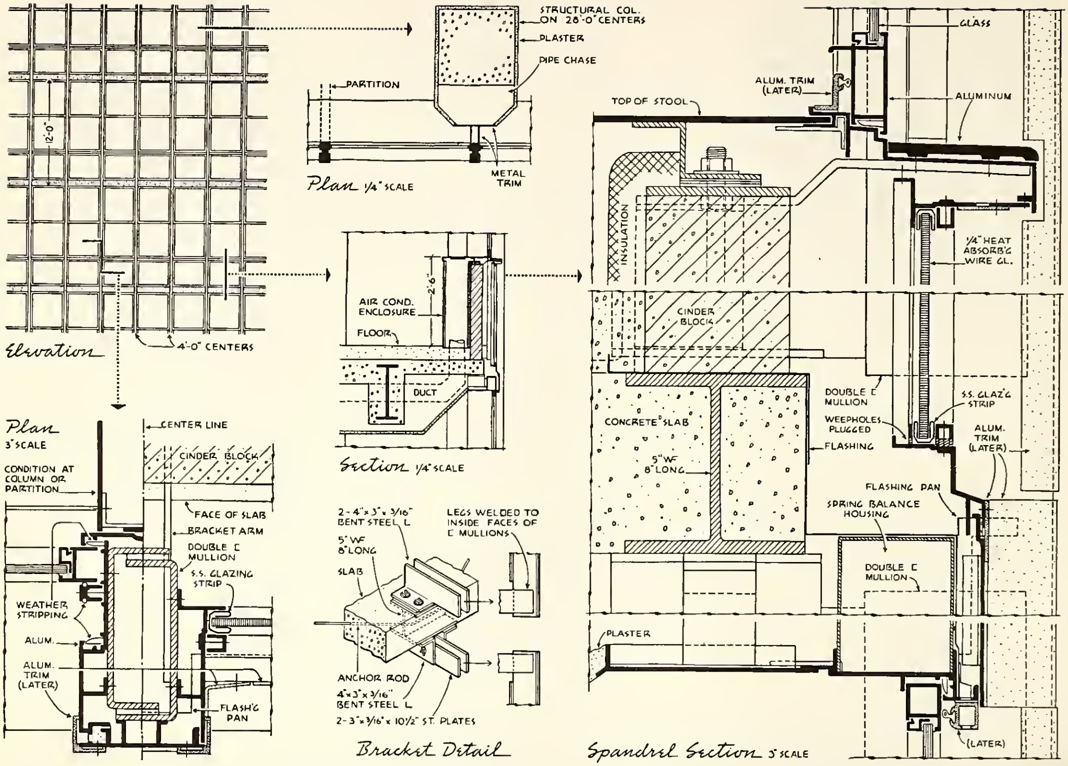


Figure 5—details of aluminum mullion-type construction in the UN Secretariat Building, New York: Wallace K. Harrison, Director of Planning.

etching can be employed when a special surface is desired. Various degrees of scratching or etching produce a wide variation in surface texture. The scratching operation is usually done by a power-driven rotating wire brush. Variations in the wire size produce the varying degree of scratching.

Most etching is done by immersing the aluminum in a heated solution of caustic soda for a period of time and then rinsing. Etched surfaces can be varied by changing the concentration of the caustic soda solution or the time of immersion.

Polishing is employed to remove any abrasive marks on the metal and is done with fine abrasives on wheels or belts. Aluminum is polished in much the same manner as other metals, but with lower wheel-to-metal pressures.

Electrolytic or anodized finishes are applied to aluminum to protect the existing surface or to achieve special coloring. The electrolytic process builds up the oxide surface on the aluminum and forms a hard shell to protect the surface from abrasion or corrosion.

Anodizing is accomplished by passing a current through aluminum suspended in a chrome or sulphuric acid solution. First, the metal is chemically cleaned, then anodized, rinsed, and sealed by a hot water bath. The oxide films built up on the surface by this process may vary from .00005" to .001" in thickness. Depth of the coating is a function of current density and time.

Organic coating processes involve preparation of the metal surface by an etching-type cleaner, prime, then paint. Most paint films used on aluminum are baked on and obtain very desirable and lasting surfaces. Many special finishes of vitreous enamels have proved successful with aluminum panels and offer a permanent finish.

construction

Architectural joining methods are generally confined to welding, riveting, and bolting. Most aluminum curtain-wall construction joined on the job has been done by bolting, mainly because of the ease of handling. Structural work employs riveting or welding. As a general rule, riveting and welding are shop procedures used for prefabricating the panels or facings.

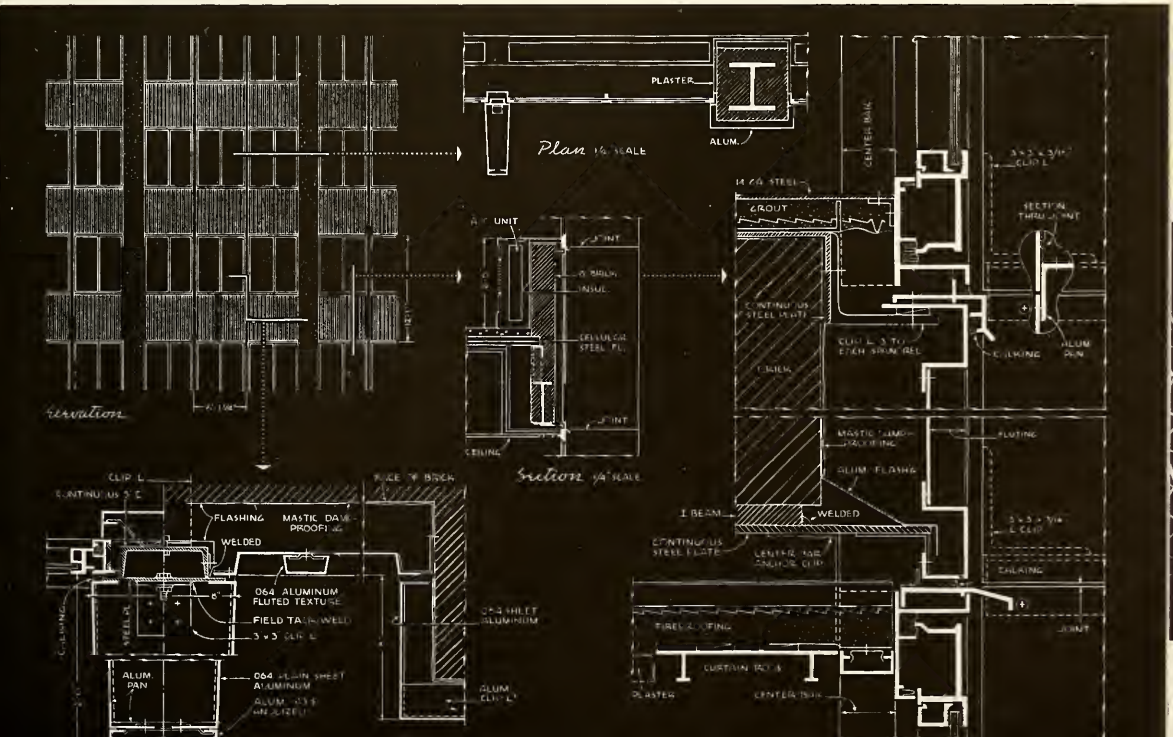
Under normal conditions, steel bolts, galvanized or cadmium plated, are satisfactory. Aluminum bolts should be used under more corrosive conditions. A wide range of aluminum rivets and bolts are currently on the market. When using aluminum bolts or rivets, 61S alloy is generally recommended.

When compensating for expansion and contraction, it must be borne in mind that aluminum has about twice the thermal expansion of ferrous metals. Expansion joints designed into the panels should allow about 3/8-inch for every 10 feet of space.

Minimum thickness of metal in extrusions and castings is governed by the process. Thickness of sheet must be sufficient to prevent buckling or oil canning. There is no "rule of thumb" or available data on recommended thicknesses as they depend on many factors including methods of forming and fabricating the wall, the area, and so on. The thicknesses shown on the details in this article are considered well chosen and so can be useful as a guide.

Contact with dissimilar metals can sometimes be damaging if moisture is present for any extended period and galvanic action begins. A coat of bituminous paint applied between the metals will prevent galvanic action.

Figure 6—detail of aluminum fins for the El Paso Gas Company Building, El Paso, Tex.: Carroll & Daeuble, Architects.

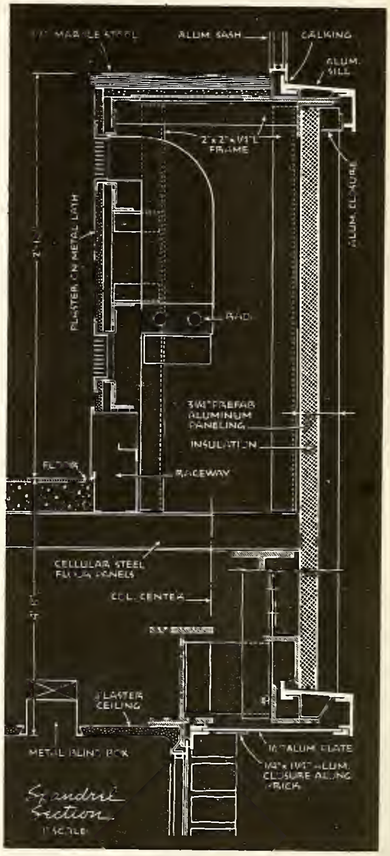


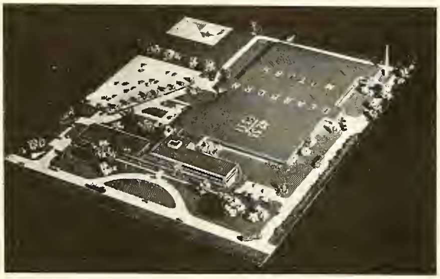
Office and Warehouse Building

Office and warehouse buildings for the Dearborn Motors Corporation, national marketing organization for Ford tractors and Dearborn farm equipment, have been located on an 80-acre site at Birmingham, Michigan *(model at left)*. In meeting the requirements of the client, Giffels & Vallet, Inc.—L. Rossetti, Associated Engineers and Architects, Detroit, have designed a structure to house the business and executive offices of the company, with a connected warehouse for storage of tractor parts, also containing shops and labs.

The office building, a three-story reinforced-concrete structure with basement, provides 125,000 sq ft of usable space *(plan acrosspage)*. Its exterior walls are of face brick, with aluminum sash. The north and east elevations are of prefab insulated-aluminum curtain-wall construction. Possessing remarkably low heat transfer and vapor transmission characteristics, each of the cellular-aluminum panels in the curtain walls is approximately 7′ 0″ high and has an over-all thickness of 3¼″ that includes a 1½″ insulation backing *(section acrosspage)*. In the roof construction, precast-cement tiles are covered with a 20-year composition roof. Throughout the building, cellular-steel floors are covered with concrete-stone fill and surfaced with asphalt tile. Metal partitions permit maximum flexibility to meet the changing needs of the office space.

Linked to the office building by a cafeteria at ground level, the warehouse covers an area of 170,000 sq ft. Its walls are principally of brick sill construction with steel sash and aluminum siding. Insulated-metal roof decking tops the shops and warehouse areas. Floors are poured concrete while the cinder-block walls separate the various elements within the warehouse.





When Charles Martin Hall first produced his aluminum buttons at Oberlin College in 1886 (a few revered ones have now become the "Crown Jewels of Alcoa," right), *the approximate price of this metal was $8.00 per pound. With a 1,350,000 ton volume of production contemplated by the entire U.S. industry for 1952, aluminum pig sells today for about 18 cents per pound.*

Alcoa Building: Lightweight Construction

BY BURTON H. HOLMES

There can be little doubt that the Aluminum Company of America's new office building, now nearing completion in Pittsburgh, weighs less for its size than any other skyscraper yet erected. Many of the most significant postwar building techniques that make lightweight construction possible have been skillfully integrated into the design of this 30-story (410′ high) structure containing 300,000 square feet of rentable floor area above the first level. The principal weight-saving elements will be found in the magnificently engineered curtain wall, in the dual-purpose type of floor construction, and in the component parts of the unique heating and cooling system. That a large number of its building products are indigenous, is a tribute to the enterprise of Pittsburgh's manufacturers of architectural materials.

the curtain wall

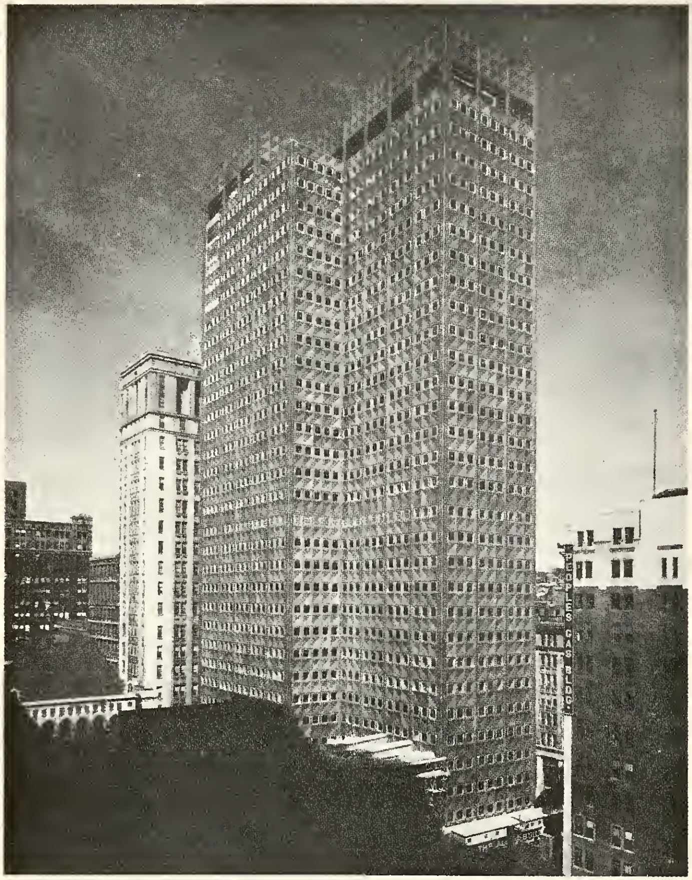
Other than containing lighter members, the riveted and bolted skeleton frame for this building is not unlike that found in most other contemporary, tall office buildings. Lightweight, foamed concrete was employed to fireproof the columns, spandrel beams, and was used, as well, in the floor of the service-core area on each typical floor. Heavily galvanized steel-angle brackets, bolted to anchors welded to spandrel steel, receive the all-aluminum panels.

The exterior facing is made up of pressed panels that are 6′ wide, 12′ high (story height), and of 1/8″ thick aluminum sheet. Stacked and stored on each floor until installation, panels were erected from within the structure, thus eliminating the need for exterior scaffolding. After the panels were shimmed and bolted to the brackets, the joints required no additional taping or calking: the exterior is entirely maintenance-free. Flanges of adjoining panels are so designed that a labyrinth excludes all penetration of rain; infiltrating air must change directions four times before being arrested at the secondary return flange. Smaller panels, extending from floor to floor and 27″ wide, cover the fireproofed structural columns that occur generally at 20′ intervals around the periphery of the structure. The metal panel is totally separated from its back-up, the dimension of the intervening space varying from 8″ at the panel edge to 1½″ at the apex of the pyramidal impression; through this space, circulating air helps to evaporate any condensation that may form.

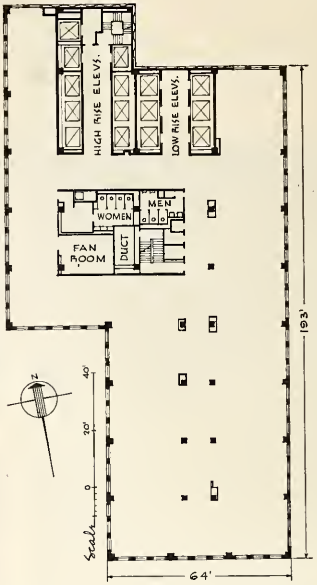
Once the skin was properly anchored, a slotted aluminum lath was installed to serve as a catcher-screen for a sprayed-on perlite-concrete back-up; a maximum of five passes of the plastering machine was required to build up a 4″ thickness. When the concrete had cured (it was designed to develop 1650 psi in 28 days and actually developed 2000), 1″ plaster was applied to metal lath furred ¾″ from the wall.

All exterior panels were anodized and a 5 percent silicon-bearing, aluminum-alloy liner material gives them an iridescent, gray appearance without the use of pigment or dye. The inverted pyramidal pattern contributes a certain amount of rigidity to the skin; however, this design was developed principally for esthetic reasons. The aluminum skin alone will successfully resist a wind load of 30 psf with a safety factor of two. The total weight of the curtain wall is approximately 34 psf; the skin weighing 2¼ psf, the 4″ perlite-concrete back-up 22 psf, and the furring and plaster about 10 psf. Other than the perlite aggregate in the back-up and the two air spaces, there is no other thermal insulation in the wall. Tests have shown that the curtain wall has a U-factor of 0.14; it is believed that this factor will be even lower after the walls have been completely cured. Although the Pittsburgh Building Code requires only a two-hour fire rating for exterior walls of commercial buildings, this curtain wall has satisfactorily passed a four-hour test.

Experience has shown that two erection crews of five men each would be able to enclose the 30-story structure with the aluminum skin in one month's time. Each



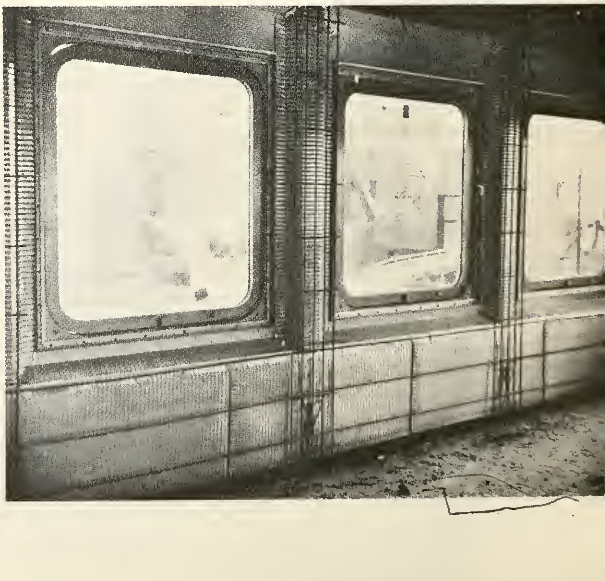
Alcoa's new home office building in Pittsburgh as it neared completion (above). *This 410′-high skyscraper is supported on open-caisson concrete piers that reach a depth of 90′ below street level. Its main tower is 64′ wide and 193′ deep* (typical floor plan, above right). Photo: Jack Holmes

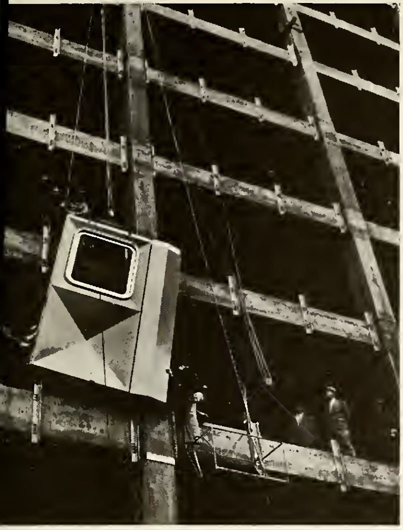


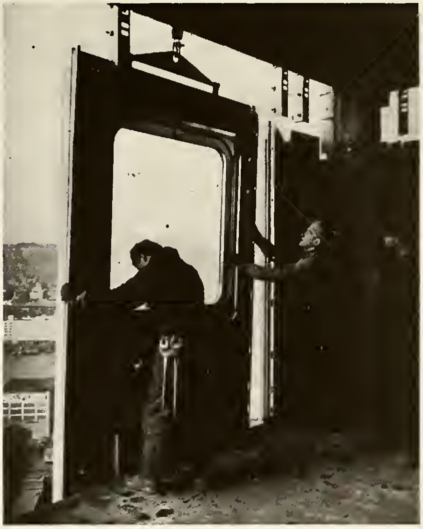
spray crew for the perlite-concrete included four men; three such crews were able to erect the back-up walls at the rate of 2½ stories per week. Compared with conventional curtain wall construction, this type of wall permitted a savings of over 3000 tons of structural steel in the framework.

At the time of erection, each panel contained a vertical-pivoted, aluminum-frame window measuring 4′-2″ x 4′-7″; sash was

After panels were anchored and glazed, slotted-aluminum lath was installed to catch sprayed-on perlite-concrete back-up (right); *wood forms protect windows while back-up is sprayed to depth of 4″* (center); *completed perlite-concrete walls after removal of wood forms* (far right). *The wood forms were used only at window jambs because of their great projection. Lastly, walls were plastered over metal lath. Note grid for heating-cooling system at ceiling.*





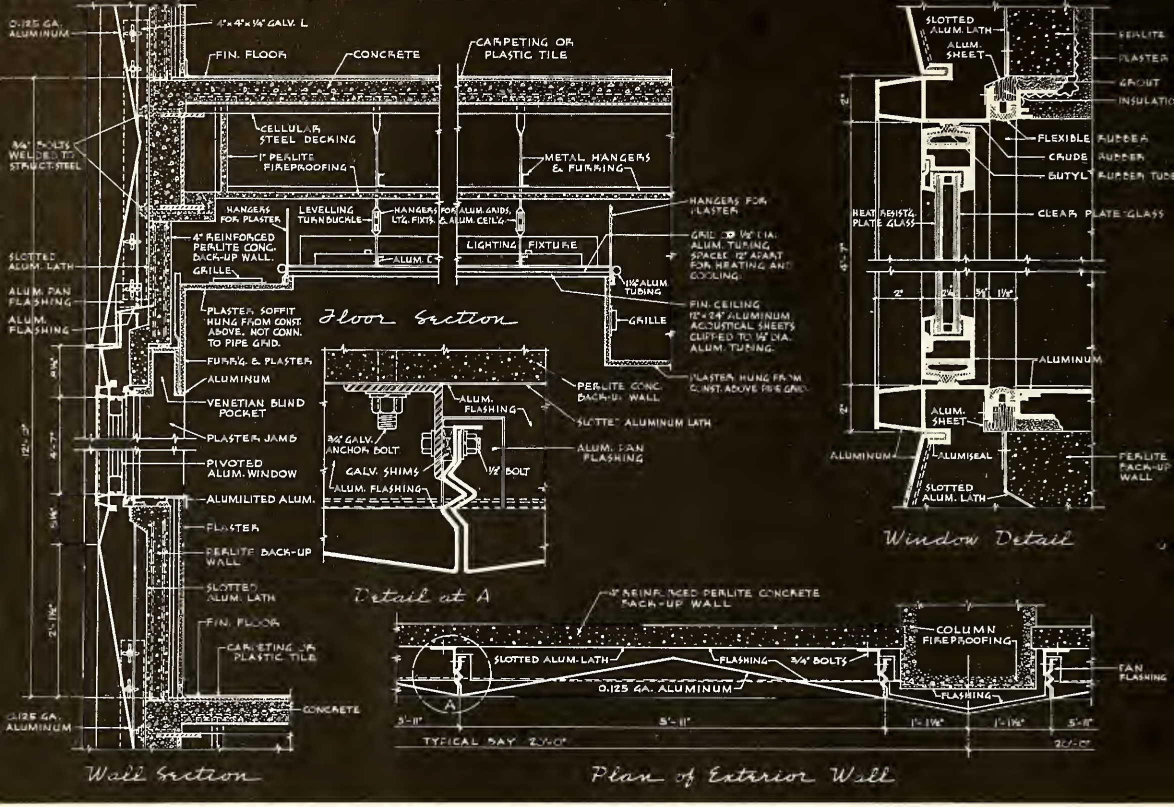


Typical aluminum panel (6′ x 12′) and column cover (2′-3 x 12′) being hoisted into position (far left). *Workmen align panel flanges with steel-angle brackets bolted to anchors welded to spandrel steel* (left). *Vertically pivoted, double-glazed windows are made air tight by rubber tube inflated by air pressure* (below).

double-glazed after each panel was in place. As the window pivots through 360 degrees, it may be washed from within the building (and at night), thereby removing window cleaning from the hazardous occupation list. To simplify further the cleaning task, all corners are rounded. A butyl-rubber tube which completely surrounds the window is inflated by air pressure to insure weather tightness. The exterior light of the double-glazing is 1/4″ heat-absorbing plate glass. Although the green-tinted glass reduces glare from the sun's rays on the inside of the building—it is not particularly helpful in reducing the summer cooling load when combined with venetian blinds—it was also selected for its compatible appearance with the surrounding gray aluminum. Standing at the first interior column line and looking out of a typical window, the observer is unaware of any green color in the glass; there is, however, a small, tinted area on the ceiling near the exterior wall.

the floor system

Following the structural steel erection by about three stories, light-gage, cellular-steel Q-floors were easily and rapidly laid in office areas surrounding the service core. As the floor cells were installed so that they lay perpendicular to the corridors, the flexibility of the electrical distri-



bution system was greatly increased. Over the 3″ cellular steel, a 2½″ stone-concrete fill of 2000 psi was poured. Carpeting was selected as the floor finish for the corridors, elevator lobbies, and will be laid in most of the offices. For some areas, such as special-purpose rooms and service areas, vinyl-plastic tile was specified. The light-gage flooring was fireproofed from below by a 1″ perlite-plaster ceiling suspended at a distance of 13″ to 16″, depending upon the depth of the wind beams.

The design load included: 50 psf live load; 7.5 psf stone-concrete fill; 7.4 psf cellular steel; 5 psf perlite plaster; and 1.8 psf combined panel ceiling and mechanical grid (dry).

the heating-cooling system

Practically all areas of the building are heated, and partially cooled, by the aluminum-panel, radiant ceiling. Below the 1″ perlite-plaster fireproofing for the cellular steel floor, 6′ x 12′ grids of aluminum tubing (through which hot or cold water circulates) are supported by a turnbuckle-leveling system. The welded grids are composed of ½″ IPS aluminum tubes, spaced 12″ on center, extending between 1¼″ IPS headers; all connections are fitted with flared-type joints. Radiant panels, 12″ x 24″ and .040″ gage, are clipped to the ½″ tubes by means of integral, continuous-type grips. For acoustical reasons, 9 percent of each panel area is perforated and a ¾″ semi-rigid blanket of glass fibers rests on top of the aluminum tubing. Seventy percent of the ceiling area is covered by the radiant panels while the remainder is occupied by lighting fixtures, diffusers, and plaster soffits containing access panels. Lighting fixtures and diffusers actually form part of the radiant surface, as they are in direct contact with the grid tubes. Such an arrangement permits the removal of a considerable portion of the heat created by the lighting fixtures before it enters the room. A mill finish on the top of each panel in situ produces only a five percent emissivity and resists radiation upwards; to the underside, however, two coats of paint were applied—one a wash coat primer and the other a baked-alkyd type—and a surface with high resistance to crazing and a 92 percent emissivity is obtained to direct radiation downward. Water distribution is through horizontal mains, located in the corridor ceiling, and through branches which extend to the individual grids.

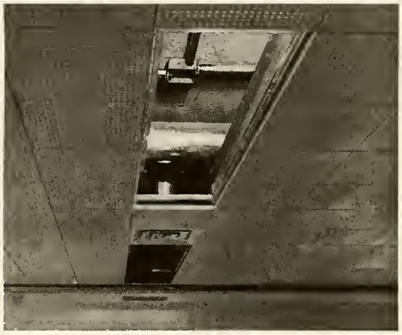
As there are no radiators, piping, or other types of peripheral air-conditioning units along the exterior wall, approximately 15,000 square feet of rentable floor area were gained by this system.

The principal source of cooling and dehumidification is two electric, motor-driven, centrifugal refrigerating machines operating with condensing water supplied by aluminum cooling towers located on the top level. This central refrigeration plant generates chilled water that is then pumped to the central station primary air-conditioning units as well as to local interchangers serving the panel systems.

The basic source of heat, purchased steam, is distributed to all blast coils in the central station air-conditioning units and is also used to generate primary hot water which is pumped to the local heat exchangers.

Primary air is conditioned in four central air-conditioning systems (one in the basement, two on the 14th floor, and one on the penthouse level) which provides 54F air all year round. This air, properly

Close-up of aluminum ducts and ceiling-piping grid on upper floor (right). *Workman installs 12" x 24" individual panel which is held to grid by integral, continuous-type grips* (far right).



Where a suspended channel or other obstruction interferes with a segment of the continuous-type grip (far left), *that segment may be readily removed by bending back and forth until breakage occurs. Lighting fixtures (not yet in place) and diffusers, in direct contact with grid tubes, form part of the radiant surface* (left). Upper right and lower photos: Jack Holmes

humidified in the winter or dehumidified in the summer, is circulated through a central shaft to the secondary fan units located on each floor. Primary air (50 percent of which is outdoor air and the other 50 percent return air regenerated by means of activated carbon) is electrostatically filtered.

Each floor is served by one secondary fan unit which mixes the 54F primary air with an equal amount of return air and then delivers it to the floor. As the room temperatures vary between 70 and 80F, depending on the prevailing outdoor temperatures, the air discharged by the secondary fans will vary from 62 to 67F—thereby providing a cooling effect at all times. The air-distribution system for an individual floor is not zoned except for the corner rooms; local booster coils and air-volume modulation permit individual temperature control in these locations.

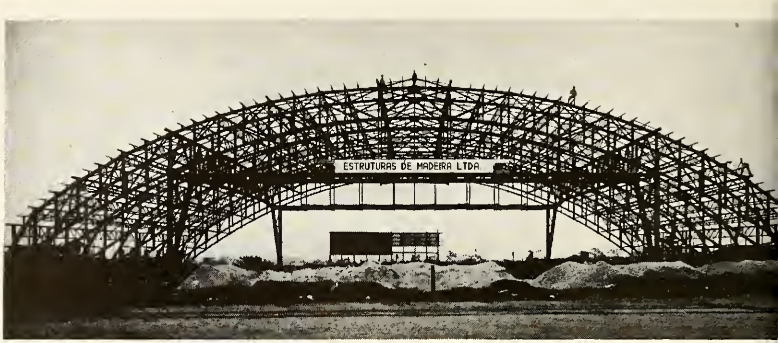
Each floor is divided into four panel zones—three exterior (facing south, east, and west) and one interior. Each has its own heat exchanger, circulating pump, and distribution piping system. Zone thermostats, which are located in a typical room of each zone and reset from 70 to 80F as the outdoor temperature rises from 70 to 95F, control the temperature of the panel water. This is accomplished by admitting either primary chilled or primary hot water to the zone heat exchangers. To prevent condensation, a safety control prevents chilling of the panel water temperature below the dew point of the conditioned areas.

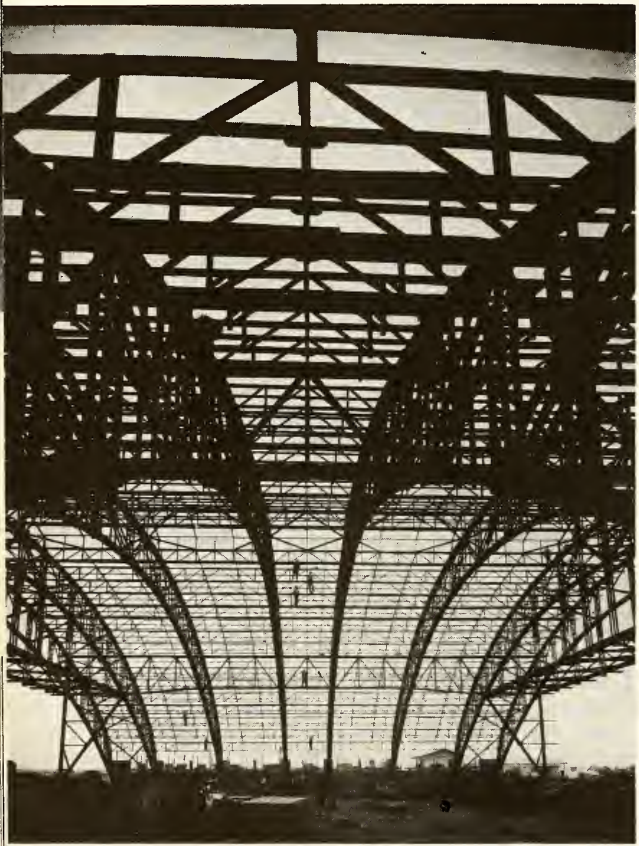
Panel temperature is under full automatic control and varies from approximately 60F at full cooling load to approximately 100F for full heating load. For quick heat up, however, panel temperatures may be raised as high as 140F. Due to the favorable heat transfer characteristics of the aluminum ceiling, water temperatures will be only a few degrees higher or lower than the actual surface temperature of the panel. The small mass and the good conductance of the aluminum ceiling also result in an immediate response of the panel temperature to the call of the thermostat. (Overcoming lag is one of the greatest weaknesses of the more conventional radiant systems—particularly floor systems.) Room temperatures which vary from 70 to 80F correspond to somewhat higher temperatures during the heating cycle and to somewhat lower temperatures during the cooling cycle, when compared with non-radiant systems.

In general, no individual room control has been provided except for the corner rooms; however, on the upper two floors, where the top executives are located, individual room control is provided by modulation of water flow through the coils. It should be recognized that in a radiant system, sensation of comfort may be obtained within a considerably wider range of temperatures.

architects and engineers

Architects: Harrison & Abramovitz, New York; associated architects: Mitchell & Ritchey and Altenhof & Brown, Pittsburgh. Structural engineers: Edwards & Hjorth, New York; mechanical engineers: Jaros, Baum & Bolles, New York; electrical engineers, Edward E. Ashley, New York. The General Contractor was George A. Fuller Company. Personnel of Alcoa's Aluminum Research Laboratories and Development Division worked co-operatively with the architects, engineers, and individual fabricators in the development and testing of the aluminum components of this structure.





Six elliptical, glued-laminated Douglas fir arches (below), spaced 20′ apart, span 180′ at Continental Can Co.'s new hangar at Morristown, N. J. Each arch has a constant cross-section of 11″ x 39″, is 48′ high at center, and weighs approximately 20,000 lbs. The three-hinged principle is employed with a pin connection at the peak and a rockerplate at the base. Wigton-Abbott Corp. designed and built the structure; Timber Structures Inc. fabricated the arches.

Magnificent wood arches (above and upper right), *in a hangar at Congonhas Airport, São Paulo, Brazil, have a clear span of approximately 230′. The hangar was designed and erected by Estruturas de Madeira S. A., São Paulo; E. Hauff, Chief Engineer.*

WOOD FOREVER

British architects are frequently amazed, and perhaps envious too, at the vast amount of wood construction that goes on annually in this country. Although there may have been a time when it appeared as though this natural resource might be exhausted, with well organized reforestration programs instituted both by government and private interests, it now seems that we shall continue to be able to employ wood as one of our principal structural materials. Because of its versatility and because of high priorities on structural steel, some of the greatest wood structures ever built were erected during World War II. Certainly one of the most noteworthy of these was a blimp hangar at Moffett Field, California, designed by the U. S. Navy Bureau of Yards and Docks. In this structure built-up timber arches have a clear-span of 237 ft! Since the war, laminated-wood trusses and arches have been widely used for spanning large areas. One of the most recent instances is at the Westchester County Airport Hangar, New York, where laminated-wood, bowstring trusses (fabricated and erected by Timber Structures, Inc.) span 248 ft! These are said to be the largest timber trusses ever constructed. In 1953, at the Montana State Univesity Field House, Architects Brinkman & Lenon used laminated-wood arches to span 201′-6″ (*page 48*). In its most familiar and abundant form, wood balloon-framing is still the backbone of most housing developments produced by the speculative builder. Some architects, however, have schemed new construction techniques in wood for homes that permit more rapid construction, reduced costs, and better structure. One example of such a construction method can be found in Alexander Knowlton's design for a home in New Canaan, Connecticut, which includes three bedrooms and was built for $12,000 (*page 44*). There is no good reason to think that plywood roofs will not prove popular in coming years, just as plywood-panel underflooring has now become accepted on an immense scale by development builders. Note how Edwin D. Thatcher detailed a plywood roof for Fishers Island, New York (*page 46*). For interior surfacing almost any veneer is available for plywood panels. Among the many are: amaranth, aspen, avodire, ebony, elm, holly, koa, lacewood, lauan, myrtle, oak, ikume, pearwood, primavera, redwood, burl, rosewood, teak, tigerwood, and tulipwood. How many can you identify?

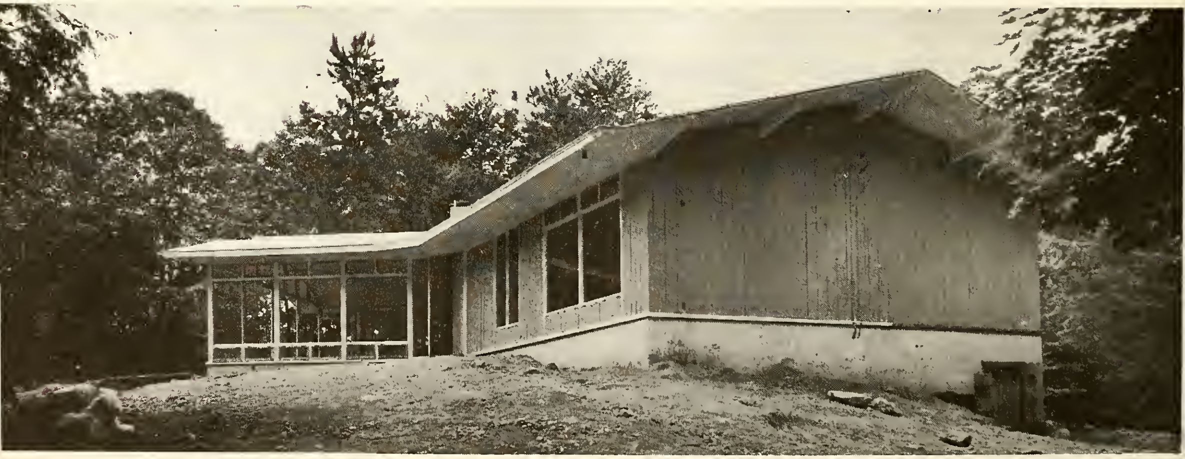
Mill-Floor Construction for Walls and Roofs

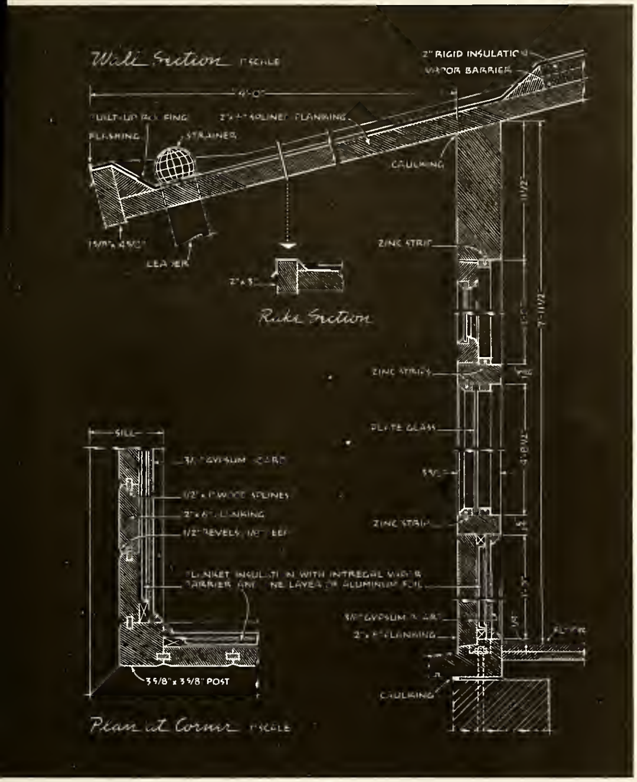
Alexander Knowlton, New York architect and architectural editor, was recently given $12,000, a hole in the ground, and a commission to prepare drawings for a three-bedroom house to shelter two adults, two children, and one sheep dog. Even though his client had already obtained ownership of the property, had made preliminary excavations, and expected to help out with some of the finish work as well, it is still evident that Knowlton had to scheme a good deal in order to deliver a house for this amount. The site is located in the vicinity of New Canaan, Connecticut, where construction costs for good residences are running from $15 to $20 per square foot. (This home has about 1500 square feet of area.)

One of the most significant factors in helping this architect to keep within his budget was the type of construction that he selected for the walls and roof. Combining the technology of contemporary building with the knowledge of yesterday's practical builder, Knowlton decided to use a mill-floor construction system for walls, partitions, and roof—but not for the floors (*see illustrations*). Originally, 2″ x 10″ planks in combination with 4″ x 4″ posts of select, structural lumber were considered for this type of curtain wall; however, this size was abandoned in favor of 2″ x 8″ planks for economic reasons. To avoid the possibility of checking, the 2″ x 8″'s were also decided against in favor of 2″ x 6″ boards. A blanket-type, aluminum-foil insulation with integral vapor barrier was applied against the splined planks and gypsum board was specified for the interior surface. Guy B. Panero & Associates, consulting engineers for this project, have determined that this type of wall has a "k" factor of 0.19. The wall is rapidly erected and the specified materials offer a choice of finishes for both exterior and interior work. These exterior walls were painted gray with a white trim.

In the roof, 2″ x 6″ splined planks are supported by 4″ x 12″ wood girders which ride over 4″ x 4″ posts and in some cases bear on masonry. A two-inch rigid roof insulation with vapor barrier underside is covered with a 4-ply built-up roofing and white marble chips which reflect 20 percent of the heat from the sun's rays.

Photo: Tom Leonard





Bedrooms and bath (wing nearest camera, photo acrosspage) *are enclosed by mill-floor curtain wall. Sections* (above) *show details of wall construction and typical bedroom window. Basic steps in erection of curtain wall are shown* (right) ; *splined 2" x 6" planks were specified for both walls and roof.* Construction photos: George H. Van Anda

Plywood Roof

For a residence on Fishers Island, New York, a one-level structure topped with a low-pitched white roof seemed best suited for the requirements of the client's family, the site, and the regional climatology (Long Island Sound). As only an air space was needed above the ceiling, ample storage having been provided at ground level, a 4 to 12 slope efficiently accommodated the dimensions of the floor plan. Such a slope excluded a shingle-type roof and offered an opportunity for another type of construction. To Ed Thatcher's way of thinking, a plywood roof system was the logical solution for this house.

His original design called for ⅝″ exterior grade Douglas Fir plywood over 2″ x 8″ rafters; 24″ cedar shingles to be used as wedging at each bearing. As the home was actually roofed, however, ⅜″ plywood panels were laid over ⅝″ plywood sheathing and wedges (*see details below*). This revision was made at the request of the general contractor who supported his semiskilled carpenters in their contention that seasonal spring winds would require a platform to work on. (This compromise was accepted ungrudgingly by the architect as his contractor agreed to furnish the additional material at no extra cost; however, Thatcher states that if he again had to design a roof for similar conditions, he would adopt his original scheme.) The 12″ overlap was dictated by the architect's own judgment. As an added safety precaution, a bead of calking was spread under the edge of each plywood panel (in about 1 in.) so that any opening that might have existed after nailing would be sealed. Jointing for most panels was similar to that shown for the ridge members (*shown below*). To avoid staining the white roof, which assists reflection of summer heat, Monel metal flashing was specified. All cutting was performed at ground level and the laying of the 4″ x 8″ panels began at the eaves, proceeding up the slope. Roofing time was less than four days for the crew of two relatively unskilled men.

Although two coats of titanium exterior paint were applied to the major areas of the roof, an extra coat was added to the exposed edges of the plywood panels. Today, after three years' exposure, examination shows that no part of the roof is in need of further painting.

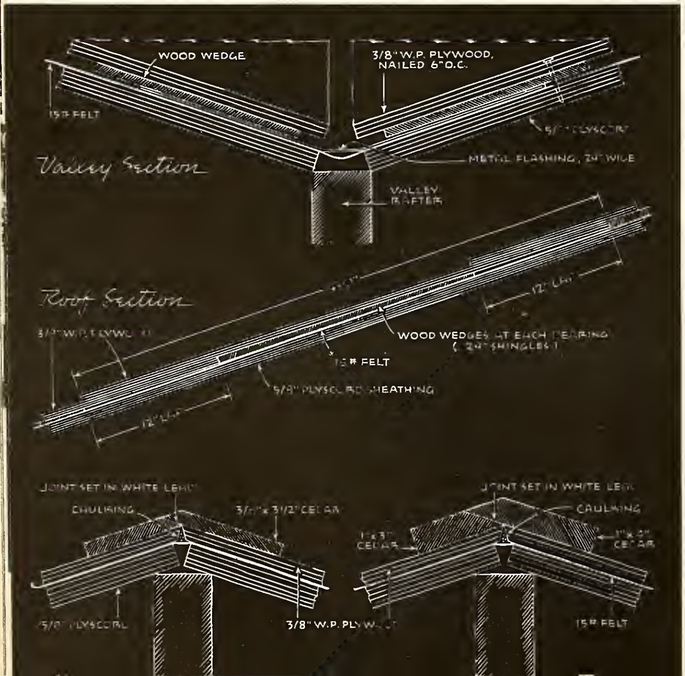


Photo of typical ridge, hip, and valley of plywood roof for residence on Fisher's Island, New York (above). *Architect: Edwin D. Thatcher, New York. Detail drawings* (left).

Plywood girders, of glued construction throughout, are massive in appearance. As monorails can be located anywhere, not just at panel points, these girders are well suited for industrial buildings. *Photo courtesy of American Roof Truss Company.*

Laminated Wood Arches and Girders

BY R. J. WADDINGTON*

Laminated wood construction, the gluing together of several laminae to form one structurally sound member, originated in Germany before World War I and later spread to Switzerland, Norway, Denmark, and Sweden. As a result of its many advantages, this type of construction has become increasingly popular in the United States, principally during the last decade. Finished members may be either curved or straight, and as they span long distances with safety and grace, they are well suited for use in churches, auditoriums, clubhouses, showrooms, gymnasiums, restaurants, farm structures, and some industrial projects.

Construction costs may be frequently reduced through the selection of laminated wood structural methods. This is especially true with some types of arches, as they act at once as both columns and roof supports. As the attractive appearance of laminated girders obviates the need of boxing, another economy is achieved. Lighting effects are often simplified. Laminated members are structurally sound and will last indefinitely. Arches of this type will not check or warp, as solid members occasionally do, and because they employ a minimum of steel, con-

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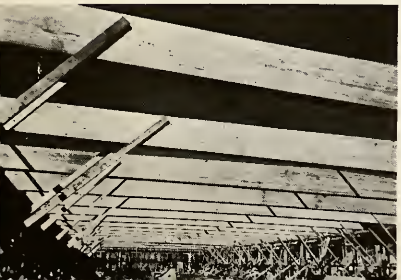
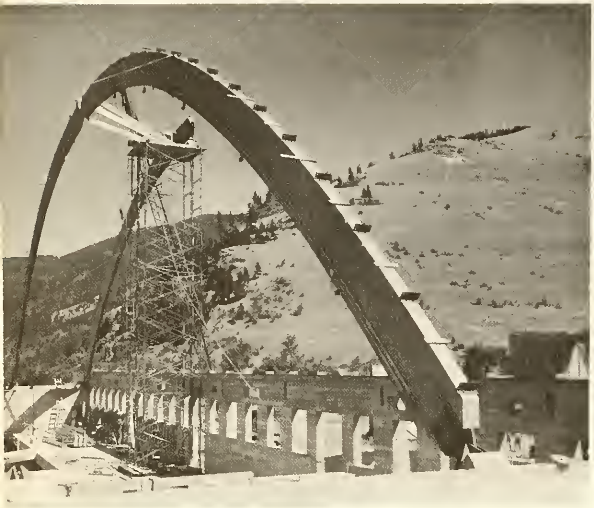
* *Vice President, American Roof Truss Company.*

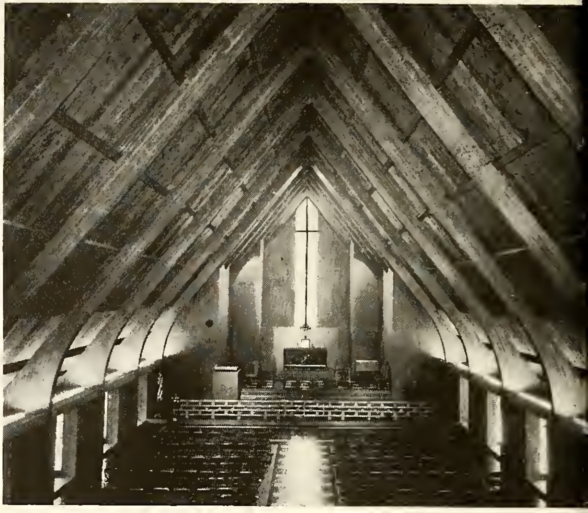
Right: glued laminated girder construction employed in a west coast warehouse. Columns are solid sawn timber.

Below: this laminated roof girder spans approximately 80 ft. Note sloping top and slight camber; erection braces at sides are only temporary. *Both photos courtesy of Timber Structures, Inc.*



Left: flat arches bear directly on wall or column bearing plates. These arches are less expensive than those with greater curvatures, as only two-inch laminations are required. *Photo courtesy American Roof Truss Company.*





Left: laminated three-hinged arches span 201 ft.-6 in. at Montana State University's new sports arena. *Photo: Ingvard Eide.*

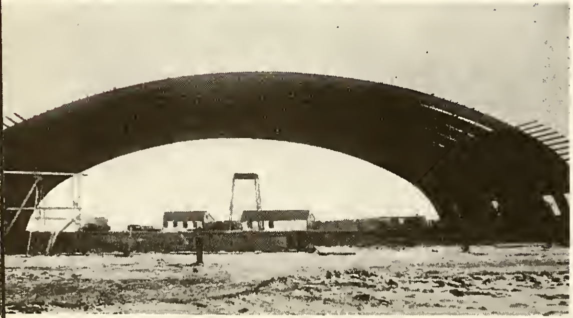
Right: glued laminated arches with timber purlins and roof sheathing. *Photo courtesy Timber Structures, Inc.*

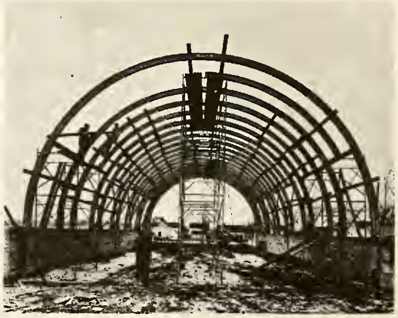
ditions likely to induce rust or corrosion are not detrimental. Little or no assembly is required at the job-site, so construction time is reduced. Vari-grained laminae provide a pleasing appearance; the size and shape of the structural members offer excellent resistance to fire; shrinkage is eliminated as only kiln dry lumber is employed.

Structural grade fir or yellow pine is generally employed in the fabrication of laminated members. Two-inch lumber is specified for laminates with very small curvatures; one inch or less where larger radii

Left: beam arches in bomber hangar, placed 10 ft. on center, span 152 ft.; arches are 35 ft. high at center. *Photo courtesy Rilco Laminated Products, Inc.*

Right: laminated rafters in this church are placed 4 ft. on center and span 42 ft. *Photo courtesy Unit Structures, Inc.*



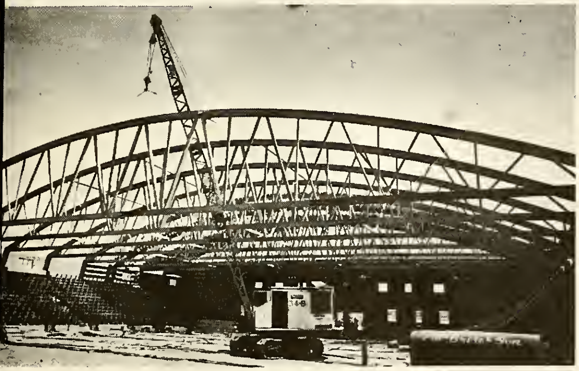


are required. Yellow pine lumber is considered best for large curvatures because of its capacity for bending. The superiority of today's glues has made possible the many excellent installations of this material. Casein glue is used primarily for indoor construction; urea-resin and resorcinal-phenol glues are especially useful for members requiring water-resistant qualities. Laminae are glued together under pressures ranging from 100 lbs. to 200 lbs. per sq. in.

A preservative usually acts as a sealer and base coat. Stain, paint, varnish, liquid wax, or shellac may be applied over this coat; the architect must specify the finish he desires, as the manufacturer prepares the exterior surfaces of the laminates in conformance with the final finish.

In shipment and erection, arches and girders should be protected from adverse weather conditions. Angles and bolts should be set in masonry before members are delivered to the site.

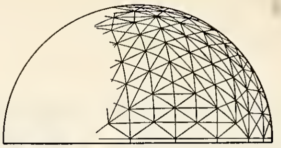
The photographs on these pages illustrate the principal architectural forms that result from the use of glued laminated wood structural members.

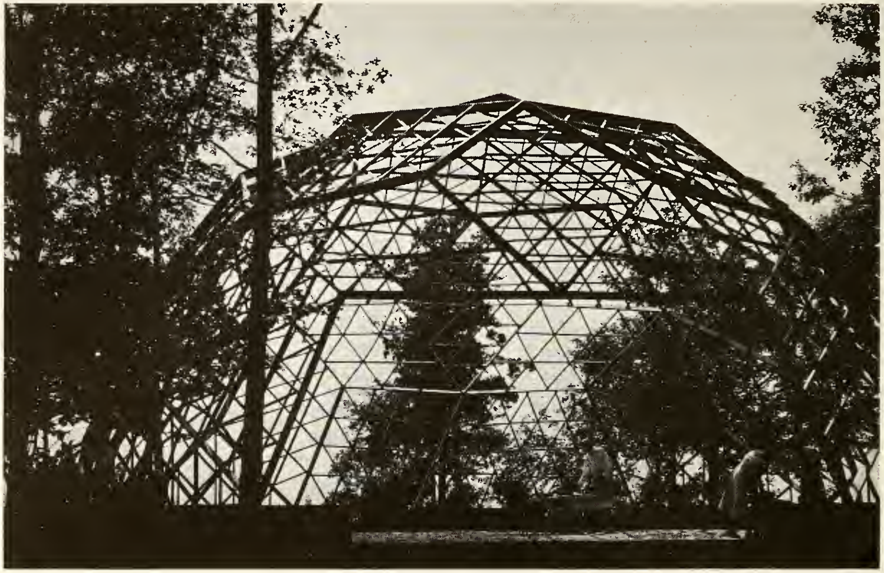


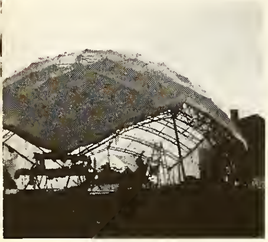
Left: arched bowstring roof trusses safely and economically span distances of 200 ft. *Photo courtesy of American Roof Truss Company.*

Below left: glued timbers were employed as the vertical supporting members of this screen tower for a drive-in theater. Towers are assembled, painted, and wired at ground level, then swung up into position. Upper photo shows laminated members attached to steel swivel shoes embedded in concrete. *Both photos courtesy of Timber Structures, Inc.*

Below: laminated structural members have many uses for farm structures. These workmen are erecting a corn crib. *Photo courtesy of Rilco Laminated Products, Inc.*





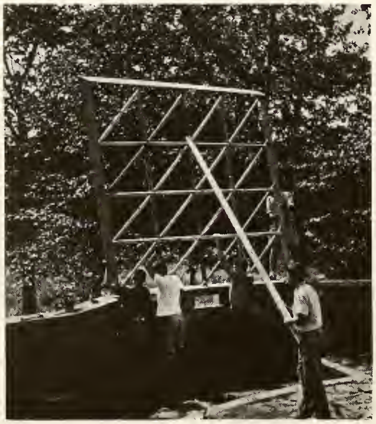


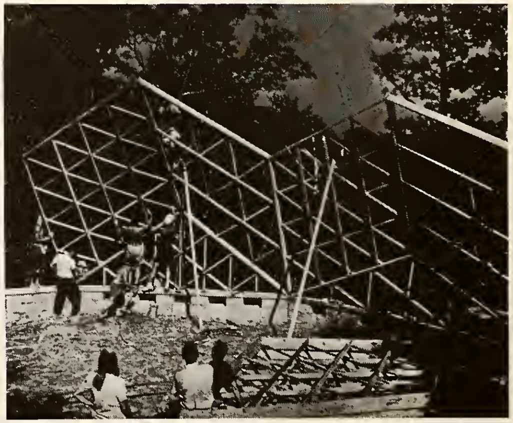
During construction, the student-builders camped in the shelter of a portable dome (top) *erected on the motel site. Man reading a good book in his rocking chair* (above) *is R. Buckminster Fuller, himself.*

On the concrete-block foundation wall, a subassembled hyperbolic diamond frame is put in place (below left). *Note the splayed shape of the 1" x 8" perimeter of the frame. Further assembly* (below right) *begins to define the dome form.*

Photos: Sam Rosenberg

Wood Geodesic Dome





E. Gunnar Peterson of Falmouth, Massachusetts, is an extraordinary architect. Not the least of his distinctions is that for 20 years he has conducted a progressive architectural practice almost exclusively on Cape Cod and the neighboring island of Martha's Vineyard, one of the most tradition-minded areas of the country. Since many of his commissions are for sites near the ocean, his trips from job to job are frequently made by boat. He calls himself "the eel-grass architect."

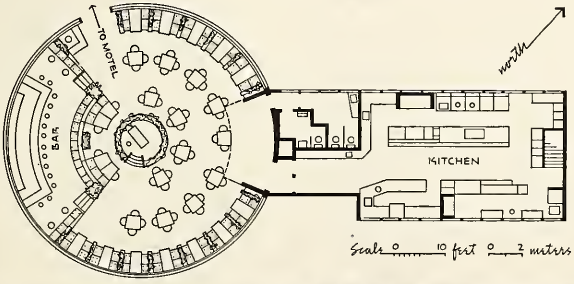
Last year, as a personal enterprise, he decided to build a modern motel in nearby Woods Hole, where steamers leave for the Vineyard and Nantucket Island. He acquired a lofty site adjacent to the village, with eye-filling seascapes seen through the trees in many directions. The motel, now open for operation, he designed himself. For the dining room, however, where he wished to span a large area economically, he tells us that "it suddenly occurred to me that a 'Bucky' Fuller dome would be the solution. It was my desire that this whole composition should be noteworthy and significant."

So, R. Buckminster Fuller engineered the dome shown here, and it was built by a group of students garnered from architectural schools in the U.S., Canada, Australia, and New Zealand.

"I consider 'Bucky's' research of historical importance," Peterson remarks, "and, as I have told him many times, I think he is developing in his dome structures and what-have-you, highly useful tools for the profession at large. To my knowledge, no one has as yet performed the feat of enclosing large areas as lightly, as economically, and as beautifully as he has succeeded in doing."

Fuller describes the Woods Hole dome as follows: "It is 54 ft in diameter and comprised of 1″ x 3″ and 1″ x 8″ Douglas fir struts subassembled into 90 hyperbolic diamonds. . . . The students processed the engineering prefabrication of parts during July and moved to the site August 1, living in a small portable dome (*small photos acrosspage*). The parts were subassembled in jigs in two weeks and finally assembled as a dome in one week. Components of the dome weigh 3½ tons and were moved to the site in one 3-ton truck. The principles of its structuring were evolved for later fabrication of corrugated stainless-steel diamonds, as an atom-bomb shock-wave-proof enclosure. . . . Peter Floyd and William Wainwright, M.I.T. graduates who acted as leaders of the student group, have contracted with Mr. Peterson to enclose the structure with . . . a new polyester-plastic clear film."

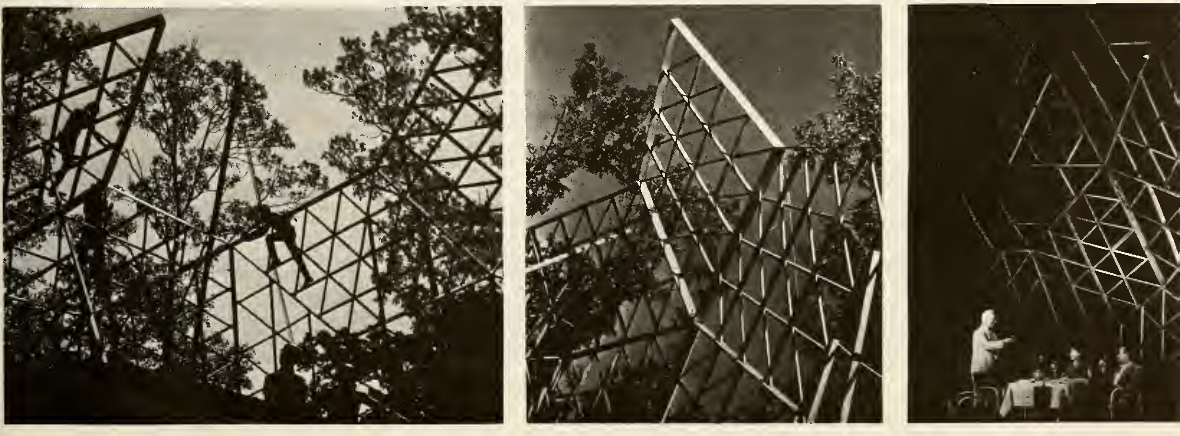
When assembled, the diamond-shape frames of the dome structure form a series of 5-pointed stars. Obviously the members will remain visible after the transparent-plastic surface is applied. "I propose to paint the structure in bone white and gold," Peterson reports, "in such a manner as to bring out the star forms."

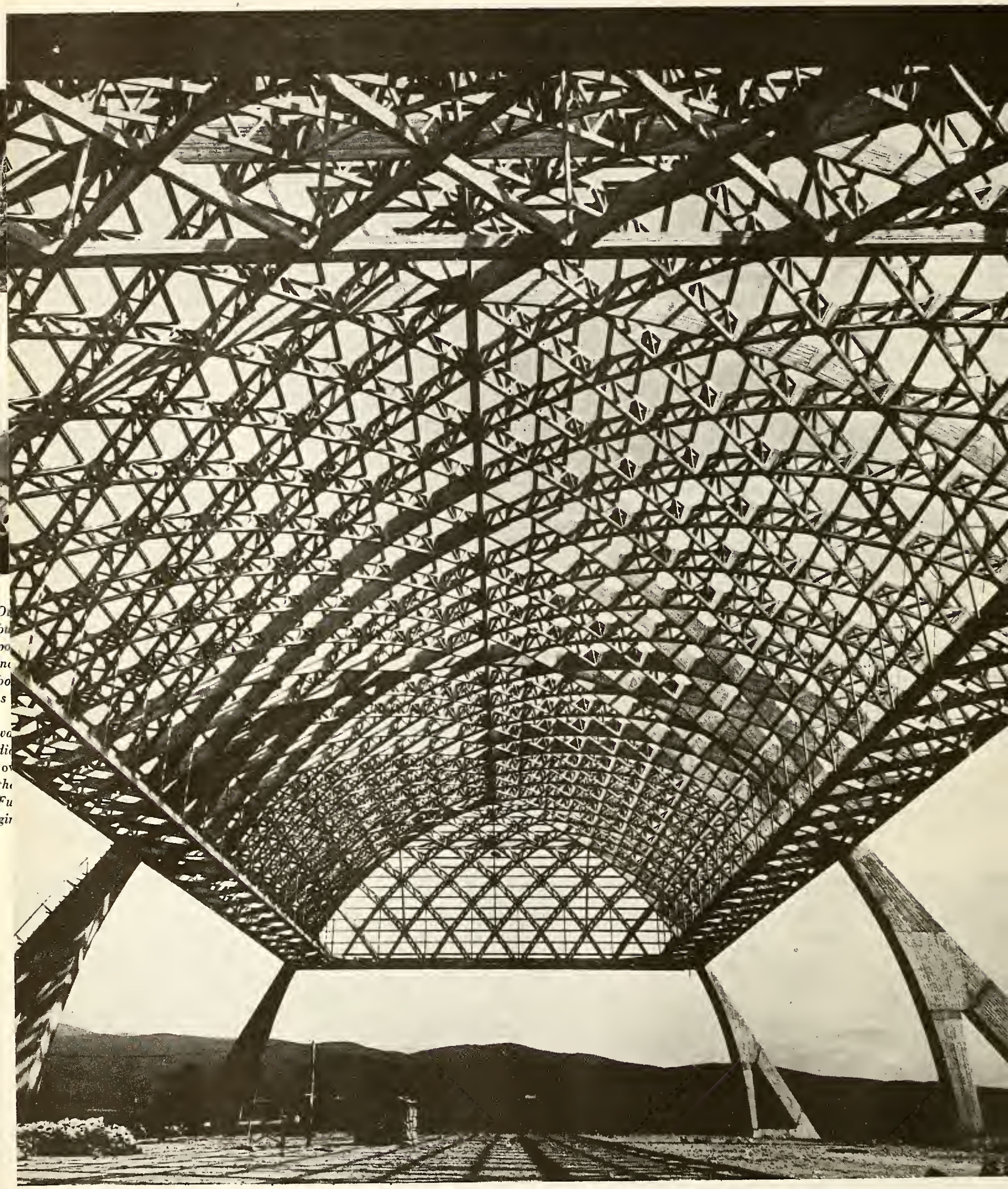


As the frames go together, they tilt ever more inward (below left).

Five frames create a giant star shape (center) *which will be painted gold.*

"Bucky" Fuller and the E. Gunnar Petersons (he is the architect who commissioned the dome for the motel he designed for himself) anticipate the opening of the restaurant and bar (right). *The exterior surfacing will be a transparent plastic film.*





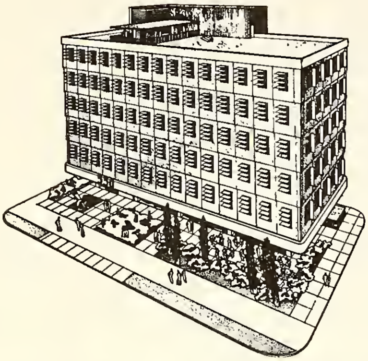
Daring hangar constructed near Rome during World War II. Designed on the lamella principle. the structure is primarily composed of precast-concrete units. Size: 120′ x 366′.
Pier Luigi Nervi, Engineer

OUR APPROACH TO CONCRETE

As we entered the second half of the 20th century, the two most recent developments in concrete construction gaining attention from American architects were lift-slab construction methods (*pages 57 to 64*) and the prestressing techniques (*pages 68 to 74*). The Walnut Lane Bridge in Philadelphia had already been completed (first prestressed linear members in the United States of any size) and Philip Youtz and Tom Slick had individually raised concrete slabs by lifting methods and had jointly assigned further research and development of method to the Southwest Research Institute. During the early days of the Korean conflict and after the NPA was formed, steel shortages intensified interest in prestressing. Because as much as one-half the amount of concrete and one-fifth the amount of steel can be saved in a single beam, inherent economies were immediately recognized. Today this refinement in structural design is being exercised with imagination and efficiency in all states of the Union. Prestressing and lift-slab construction have been combined successfully by Prestressing Incorporated, at San Antonio, and a large warehouse was completed in 1953 using these methods of concrete design. In Winnipeg, using "conventional" lift-slab methods a six-story structure was raised to house a commercial enterprise. Profs. J. Hoogstraten and J. J. Borgford, of the University of Manitoba, were the consulting engineers.

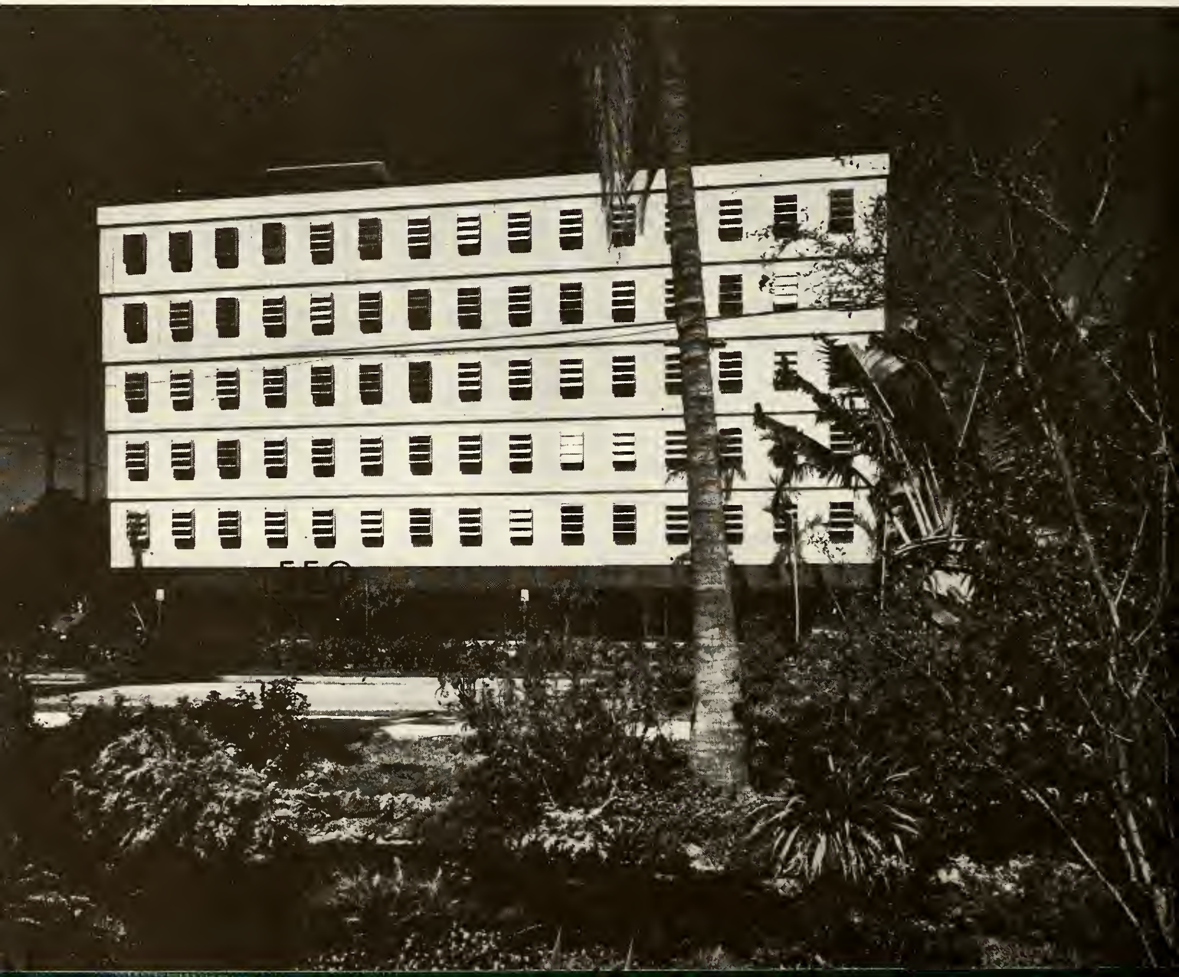
Reports indicate a sizeable increase in the use of precast modular units. In many instances, these precast units can be improved and reduced in cost by means of prestressing—especially for beams up to 100 ft and modular roof panels with spans up to 35 ft. General contractors are often setting up job-site casting yards where precast members can be turned out under job conditions just as cheaply as yard-cast members—with the added advantage that freight costs become unimportant.

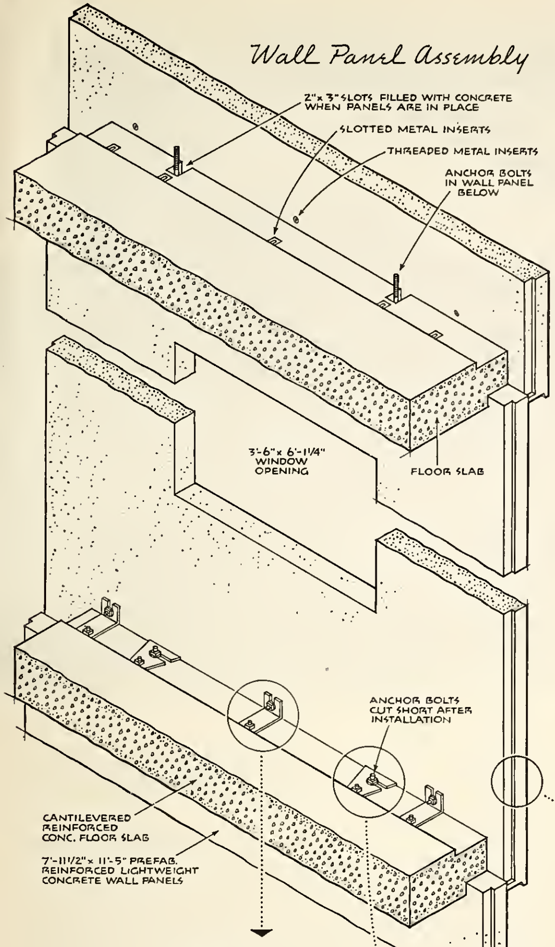
While interest in the use of thin-shell concrete construction has continued in this country, some architects and engineers abroad have refined their concepts and a few pioneers are thinking that doubly-curved surfaces are the most appropriate where a material like concrete molded at the site is to be used. Examples of this type of structure have been successfully executed in France and Italy by such men as Pier Luigi Nervi, engineer, and Prof. Giorgi Baroni; in South America; and in Mexico by Felix Candela, architect (*page 2*). As yet, no such structure has been erected in the United States although some are presently in the design stage. Hyperbolic-parabolic surfaces in metals and concrete, however, have been tested.



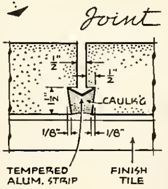
550 Building, Miami, Florida

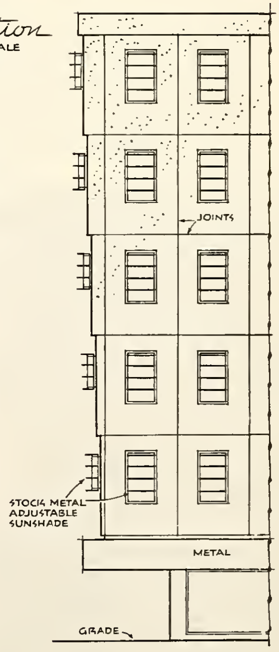
Robert Law Weed and Associates, Architects and Engineers
Jorgensen & Schreffler, Structural Engineer
R. L. Duffer, Mechanical Engineer
J. Y. Goach Co., General Contractor

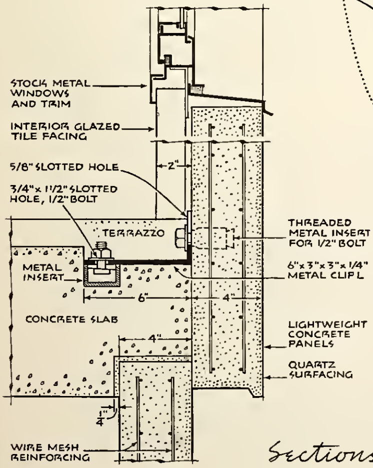


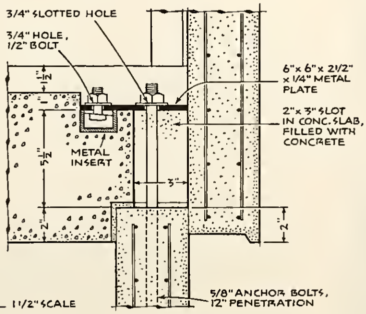

Wall Panel Assembly
2"x 3" SLOTS FILLED WITH CONCRETE WHEN PANELS ARE IN PLACE
SLOTTED METAL INSERTS
THREADED METAL INSERTS
ANCHOR BOLTS IN WALL PANEL BELOW
3'-6" x 6'-1 1/4" WINDOW OPENING
FLOOR SLAB
ANCHOR BOLTS CUT SHORT AFTER INSTALLATION
CANTILEVERED REINFORCED CONC. FLOOR SLAB
7'-11 1/2" x 11'-5" PREFAB. REINFORCED LIGHTWEIGHT CONCRETE WALL PANELS

RUDI RADA


Joint
1/2"
1/2"
1/4 IN
CAULK'G
1/8"
1/8"
TEMPERED ALUM. STRIP
FINISH TILE

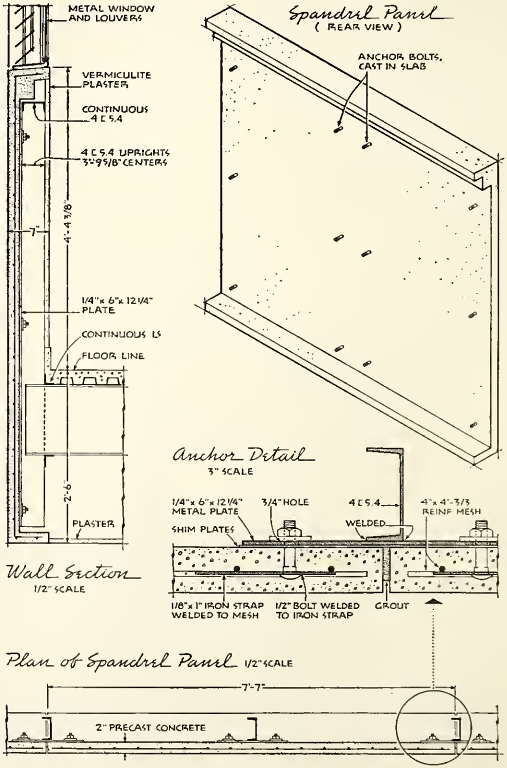

Elevation
1/8" SCALE
JOINTS
STOCK METAL ADJUSTABLE SUNSHADE
METAL
GRADE


STOCK METAL WINDOWS AND TRIM
INTERIOR GLAZED TILE FACING
5/8" SLOTTED HOLE
2"
3/4"x 1 1/2" SLOTTED HOLE, 1/2" BOLT
TERRAZZO
METAL INSERT
6"
4"
CONCRETE SLAB
4"
1/4"
WIRE MESH REINFORCING
THREADED METAL INSERT FOR 1/2" BOLT
6"x 3"x 3"x 1/4" METAL CLIP L
LIGHTWEIGHT CONCRETE PANELS
QUARTZ SURFACING
Sections 1 1/2" SCALE


3/4" SLOTTED HOLE
3/4" HOLE, 1/2" BOLT
1/4 IN
5 1/2"
METAL INSERT
3"
2"
6"x 6"x 2 1/2" x 1/4" METAL PLATE
2"x 3" SLOT IN CONC. SLAB, FILLED WITH CONCRETE
5/8" ANCHOR BOLTS, 12" PENETRATION

Mid-Wilshire Building, Los Angeles, California

Victor Gruen, Architect
R. L. Baumfeld, Associate
Edgardo Contini, Consulting Engineer
Charles Kahan, Mechanical Consultant
R. P. Randall, Electrical Consultant
Waale-Camplan Co., General Contractor



The Lift-Slab Building Method

BY RONALD ALLWORK

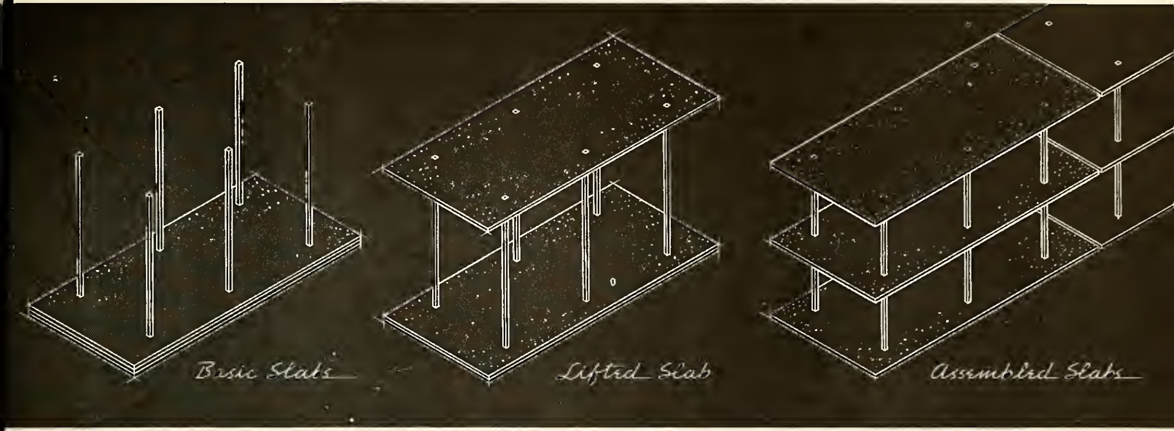


Figure 1—isometric drawings of the principal steps in the erection of a two-story structure by the lift-slab system of construction.

The Youtz-Slick lift-slab system is an ingenious construction method designed to cut building costs and save scarce materials. Developed by the Southwest Research Institute, this system has been thoroughly tested by actual construction and found to be well suited for industrial projects. Some 15 buildings of various occupancies, ranging in size from 2000 to 40,000 square feet in area have been completed; at least five more, totaling 450,000 square feet, are reported to be now under construction.

The success of the lift-slab method is largely due to its simplicity and to the obvious fact that it is more economical to construct a concrete slab on the ground than in the air. In the operation of this system, *(Figure 1)* the foundations and grade slab are constructed in the conventional manner, with columns (usually of steel) erected in place.

A separating medium, such as paper, is then laid over the finished grade slab. Steel collars are slipped over each column and after reinforcement for the second floor slab is placed *(Figures 2 and 3)* the concrete is poured. Only an edge form is required. The steel collars at each column become an integral part of the slab. When the second floor slab has set to strength, paper is again laid and the third floor or roof slab is constructed on top of the second floor slab in the same fashion.

As soon as the slabs have been cured, special hydraulic lifting equipment is installed on the top of each column. The slabs are lifted to their permanent positions and welded to the columns.

special lifting equipment is necessary

The equipment developed by the Southwest Research Institute is made available to builders through licensees; charges are based on the area of slab raised. The lifting jacks are designed for an individual load of 78,000 pounds. Mounted on the tops of the columns, they raise the slab by means of tension rods attached to steel collars that have been embedded in the slab. The lifting action of the hydraulic jacks is regulated at a central control panel *(Figures 4 and 5)* to maintain a simultaneous lifting rate at all points. Control is obtained to within one-sixteenth of an inch at a lifting rate of about four feet per hour. In most cases, the equipment is capable of lifing two, or possibly more, floor slabs at one time.

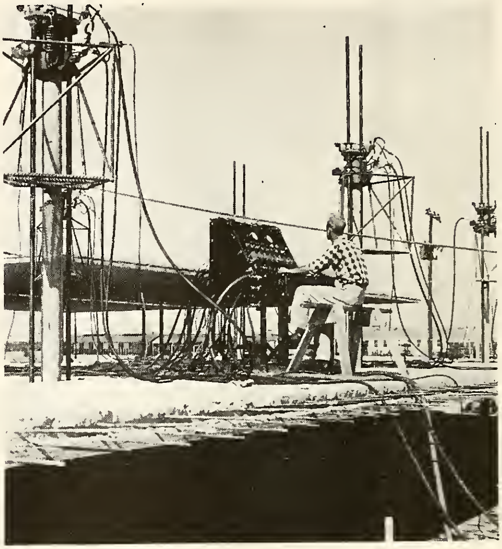
engineering considerations

The design for the steel collar is based on the assumption that the collar will become a shear connector and that the plate of the collar will act as a part of the column head. An investigation of the section modulus at several points in the collar is therefore desirable and must be based upon the moment produced by the loaded area affecting that particular portion of the collar.

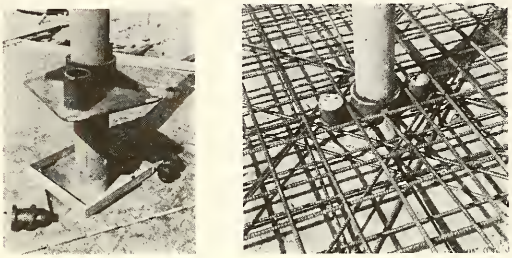
The design of the column must take into consideration the conditions that are to be met when (1) the column is fixed under static load conditions and (2) the column is used as a lifting support and acts in free cantilevers. Because the slenderness ratio for this investigation is double that of the fixed position, the cantilever condition is critical.

From the standpoint of architectural design, the column spacing is of utmost importance. Wherever possible, it is desirable to space columns to make use of the free cantilever on all slab edges. Panel bays offer the best conditions for lifting operations.

Figures 4 and 5—control console *(below)* enables operator to maintain a simultaneous lifting rate for all jacks. 18′ square bays *(left)* have a 7′-perimeter cantilever which is maximum for a 6″ slab.
Photos: Altmann Factory: courtesy of James Stewart & Co., Contractors



Figures 2 and 3—in this textile factory, glass-fiber acoustical tiles were used *(below, left)* to separate grade and roof slabs. After steel collar was dropped into position, reinforcement placed, and tension rod sleeves protected *(below, right)*, the roof slab was poured.



The present design of the lifting equipment limits the size of the columns to a maximum 10-inch round or 8-inch square. Various sizes and types of pipe columns have been used; square columns have been fabricated from steel angles welded together to form a box. The use of concrete columns is feasible. The most economical column spacing is from 18 to 24 feet. Slab areas up to 12 columns can be lifted at one time; areas including 8 and 12 columns have been proven most economical.

Where isolated footings are designed for a column, the column is considered as a cantilever retaining wall and the toe pressure and overturning moment are calculated. When the column is to be used for partial support in wind bracing, the wind load also is considered.

The method followed in designing the slab is the same as that employed for any conventional flat slab poured in place. As pointed out, a cantilever at the edge of the slab (approximately equal to one-third of the adjacent span) is considered a desirable aid in balancing the moments at the column; however, columns may be located at the perimeter if necessary. Under cantilever conditions, the flat-slab panel design divides the plate into column strips and middle strips; the reinforcing steel is laid out with a proportional amount of calculated steel to each strip. In order to obtain the required amount of reinforcing, each panel is designed as a continuous frame by the mechanical means of moment distribution.

economic considerations

Actual experience of contractors who have undertaken to employ the Youtz-Slick method has shown that substantial savings can be realized. Economies gained through speed of erection, the virtual elimination of formwork, and the use of labor on the ground rather than in the air are the factors responsible for the low costs. Ford & Rogers, San Antonio architects of a textile factory for the Bernhard Altmann Texas Corporation, in which this method was used *(all photos this page)*, report that selection was based purely on economic considerations. They state that the contractor's proven costs (not estimated) showed that the tying of reinforcing steel on the ground resulted in a 50-percent saving; that concrete finishing at ground level also saved 50 percent. A 6-inch lift slab with 1-inch insulation and a 20-year tar-and-gravel roof plus ¾-inch acoustical tile on the ceiling cost 98 cents per square foot in place; the conventional steel-bar joists with 2½-inch poured gypsum deck, 1-inch insulation, and 20-year built-up roof were figured at $1.53.

Acoustical tile may be used in lieu of paper as a separating medium. After the tile is placed on the grade slab, the reinforcing is placed and the concrete is poured. When the slab is lifted, the acoustical tile adheres to the slab, thus serving three uses—separator, insulator, and noise reducer. (Glass fiber tiles were specified by Ford & Rogers for the Altmann textile factory.) Electrical conduits and outlets, slots for pipe hangers, and other equipment may be set in place on the ground before the slab is poured. An estimated 30 percent in costs is saved by installing the electrical work in this manner. A 10 percent saving in plumbing and heating can also be realized when sleeves, stocks, and other openings are provided for in the slab pouring.

Indirect savings accrue when column interference is eliminated in the erection of exterior curtain walls, and through the elimination of all load-bearing partitions. The smooth ceiling of the flat slab makes the installation of ductwork and piping easier, simplifies the finishing, and generally eliminates the need for false ceilings.

Structural Aspects of the Lift Slab

BY FRED E. KOEBEL*

Many articles have appeared in recent months extolling the architectural considerations, the cost benefits, and general adaptability of the Youtz-Slick Lift-Slab Method of Building Construction. However, few if any of these articles have discussed the structural aspects and considerations involved in the method. The purpose of this paper is to discuss in some detail these factors involved in the structural design of a lift-slab building.

As many engineers involved in the design of lift-slab structures have found, the analysis and design is similar in many respects to any other building design and analysis. The basic differences involved in the Youtz-Slick design pertain primarily to the column design and the collar design.

column design

Column design for lift-slab introduces an entirely new philosophy of column action to the design engineer. In this method slabs are poured one on top of the other and then the slabs are lifted into position by hydraulic jacks sitting on top of the column. Thus, when the first slab is being lifted the column has no restraint at the top and is fixed or built in at the bottom. The hydraulic jack is centered on the column at the top, thus applying a concentric loading to the column which is equal in magnitude to the dead load reaction of the slab being lifted. If the slenderness ratio of this column is computed, it will be found that the ratio is exceedingly large, thus making the analysis problem one of stability instead of inelastic action. It has been shown that for large slenderness ratios the Euler equation will give the critical load value which initiates buckling of the column. For that reason, Euler's equation with an appropriate factor of safety is used for the structure. In any standard text the Euler equation for pin-ended columns is defined as:

$$P=\frac{\pi^2 E I}{L^2}$$

where P=critical load value initiating buckling
E=modulus of elasticity of the material
I=moment of inertia of the section
L=free length of the column

With a column built in at the bottom and free at the top, it can be shown that $L=2l$, where l=free length of free standing column.

Thus, the initial equation for pin ended columns is reduced for this case to:

$$P=\frac{\pi^2 E I}{(2l)^2}=\frac{\pi^2 E I}{4(l)^2}$$

The problem for the design engineer then is the determination of an adequate safety factor. This safety factor is included because of eccentricities within the column section, impact at the initial stage of the lift, and the usual reasons for providing safety factors.

After lifting the roof slab and fixing it to the columns, the next slab is raised into position. This condition of loading is usually not as severe as the initial condition outlined above. The slenderness ratio of the column in this condition of loading is usually reduced substantially and for this reason is not critical.

The column strengths are checked during any succeeding lifts until all slabs are fixed in position. At that time the column is similar to any building column and it is checked by any of the empirical equations recommended in building codes. The usual equation used is a parabolic formula recommended by the American Institute of Steel Construction for axially loaded columns with values of $\frac{l}{r}$ less than 120.

$$\frac{P}{A}=17{,}000-.485\frac{l^2}{r^2}$$

where $\frac{P}{A}$=allowable axial stress
l=free length of column
r=radius of gyration of the section

Columns in general use in the method include pipe columns, H columns, and square columns formed of angles and plates. Concrete columns are also used successfully. It is highly desirable to obtain column sections that are symmetrical about both major axes. For that reason pipe columns and square columns are used more frequently.

collar design

The lifting collar, a cast-steel plate, serves a triple purpose in a lift slab. The collar is placed around the column and cast into the concrete slab. Openings are left in the collar to fasten the lifting rods and thus the slab is lifted through the collar. After the slab is raised to position shear connection plates are fastened from the column to the collar, thus supporting the slab. The third and perhaps most important function of the collar is its behavior as a column capital. The reaction of the slab on the column is distributed around the periphery of the collar instead of around the smaller periphery of the column.

The collar is a plate stiffened by gussets with holes provided for the column and lifting screws (*Figure 1*). In the analysis of a lift slab it is assumed that the stiffness of the collar is many times greater than the stiffness of the slab; hence, the collar is assumed to be rigid and nondeflecting. (Several tests have proven this assumption satisfactory.)

In choosing the size of the collar, two items should be carefully checked. First, the shear developed at the reaction is of prime concern. Secondly, the bearing stress between the collar and concrete as a result of the reaction must be kept within allowable limits. In ascertaining the magnitude of shear stress, since it has been assumed that the collar does not deflect, the equation $v=\frac{V}{bjd}$ can be used:

where V=reaction due to total load
b=the periphery around the collar (defined as the width of the collar plus twice the effective depth of the slab around the entire collar)$=4(b+2d)$
j=assumed as .875
d=distance from center of gravity of tensile reinforcing to the compression face of the slab.

The maximum allowable value of this shear stress is taken as .025f'c where f'c is the ultimate compressive strength of the concrete at 28 days. It can be seen that the value of shear stress developed will control in many instances the depth of slab and size of collar plate. It is also possible to provide a shear head composed of stirrups placed around the collar at the critical area to resist added shear. It is recommended that if this is done the maximum shear be held to .04f'c with the stirrups thus designed to take .015f'c.

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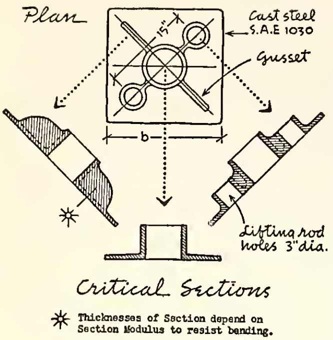
* *Structural Engineer, Institute of Inventive Research, San Antonio, Texas*



ANALYSIS OUTLINE OF COLLAR STRENGTH

(1) Determine section properties at critical sections.

(2) Compute Bending Moment at critical sections, assuming reaction distributed uniformly on base plate area. (This is not true on edge collars.)

(3) Determine stresses set up at critical sections by flexure equation.

Figure 1—typical details of lifting collar.

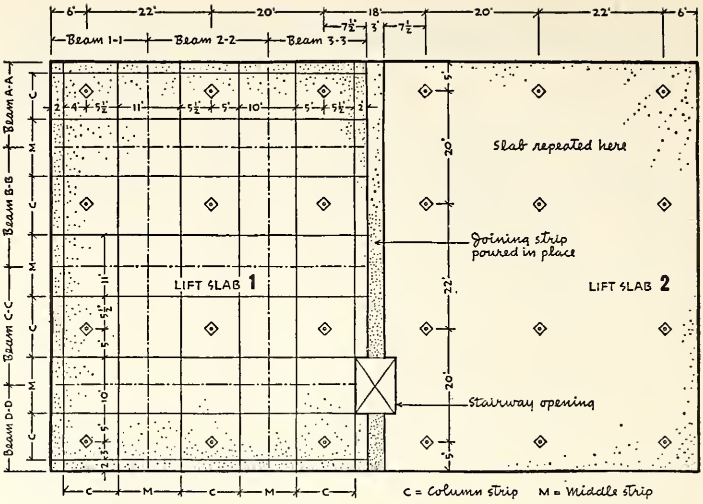


Figure 2—layout of beam, column, and middle strips for typical slab.

The collar sections are designed by evaluating the bending moments and stresses developed due to the reaction of the slab at the critical sections as shown (*Figure 1*). The added sections due to gussets may be included in the section properties.

The connecting plates used to fasten the slab to the column are designed to transmit the reaction at the slab into the column by shear only in one- and two-story construction. For multistory construction and buildings subjected to high lateral loads, other methods are used.

slab design

Slabs used in the method are designed according to the specifications for flat slabs set up in the American Concrete Institute Building Code. The thickness of the slab is determined so that shear stresses and compressive stresses at the critical sections do not exceed the allowable stresses for the concrete used. The minimum thickness of slab, however, is limited to $\frac{L}{36}$ where L is the length in inches of the largest span.

In general, it is highly desirable to plan lift slabs in lifts of 12 columns each. This decreases the number of joints between sections of slab and the total time spent in setting equipment. The most efficient span lengths in conventional flat plate are between 20 and 24 ft with the ratio of spans no more than 1.33. Recommended superimposed loads should not be more than 150 psf because of the deflection characteristics of the flat plate.

It has also been found highly desirable to provide cantilevers because of the corresponding reduction in positive moment in the interior spans and the uniform distribution of shear resulting at the column area. For these reasons cantilevered slabs are recommended. However, in the vast amount of construction already complete, there are many slabs with columns at the periphery of the slab. If the load-bearing walls are used, it is conceivable that the slab could be lifted with cantilevers and then the live load distributed with the effect of the load-bearing wall reaction included.

For the analysis of bending moments due to dead load and live load, the slab is divided into separate beams consisting of a row of columns and strips of slab bounded by the centerline of the slab on either side of the column row as shown (*Figure 2*). These beams are taken in the longitudinal and transverse directions of the building resulting in the two-way pattern for the reinforcing steel. If the slab is continuous the resulting beams may be analyzed by any method of indeterminate structural analysis—the more common being Moment Distribution, or Slope Deflection. The analysis for live load can be made directly if the load is definitely known. Live load is movable and can be placed in different panels. Critical moments should be analyzed with the live load placed in panels so that maximum critical moments are obtained.

After the maximum dead load and live load moments are obtained, they are divided into column strips and middle strips in each direction. A column strip is defined as two adjacent quarter panels on either side at the column centerline, while a middle strip is defined as a strip one-half the panel in width and symmetrical about the panel centerline. These moments are divided into column strips and middle strips in the percentages recommended in the A.C.I. Building Code. The area of steel required is then obtained and spacing and length of bars required determined in the usual manner.

The design of a lift slab is thus very similar to the design of any conventional flat slab. However, it should be pointed out that due to the fact that the dead load deflection characteristics of the slab are already present before the slab is fixed in position, certain unique conditions exist after the slab is fixed at the columns. If load bearing walls are used to support the cantilever span after lifting, and the deflection of the cantilever is not removed, the dead load will not react at the wall. The live load will react at the wall, however, and the resulting span must be provided with adequate steel to resist the resulting positive moment. If the deflection is removed from the cantilever, adequate steel must be provided to resist the resulting positive moment due to live load and dead load. The interior spans must also be adjusted for steel due to the change in end span support conditions.

Since lift slabs are broken into a maximum of 12 column lifts, and building slabs are often composed of many more columns, it is necessary to join the lifted slabs by some means. This can be done by forming a moment joint or a shear joint between the adjacent slab edges after the slabs are lifted and fixed on the columns. A moment joint is made between two sections of the slab that are lifted as cantilevers and hence have dead load deflection due to the cantilever action. If both cantilevers are the same length deflections are similar and a joint can be made which will be required to resist only live load moment in the now continuous span. Often, however, the cantilever spans which are to be joined are not the same length and the deflection of each span becomes different. In this case it is advisable to shore both spans up to the level of the slab at the column connection, and then pour the joint. Thus the joint and the entire span length must be reinforced for the effects of the now continuous span for both dead load and live load. Thus there is an increase in positive steel. However, the steel at the cantilever support supplied for lifting is now, in the final position, usually adequate for negative moment with dead load and live load.

When the slab is raised to its final position it is fixed to the column by means of shear plates welded to the column and to the exposed base of the lifting collar as shown (*Figure 3*). The length of the plates and corresponding amount of weld is determined by the amount of load transferred to the column and the allowable shear stress in a welded joint. These shear connections are usually plates placed on all four sides of a square or rectangular column or bent plates fitted to the curvature of a pipe column.

footings and foundations

The design of footings and foundations for a lift slab structure is similar in all respects to the design of footings and foundations in a conventional building. Many lift-slab buildings are designed with curtain or nonload bearing walls. This means that the entire dead load and live load is taken by the columns and must therefore be transferred directly to the ground by the footing. Thus footings often become large and their design of major importance.

The first step in the design of the footing is to determine the condition, type, and bearing capacity of the soil beneath the footing and in surrounding areas. This determination is important and should be done thoroughly. After the bearing capacity of the soil is known, the size, the steel areas required, and the thickness of footing can be determined. If the footing is deep, the load can be transferred from the column to the footing by means of a pedestal. Usually lift-slab construction is done with steel columns. In order to transfer stress from the steel columns to the concrete footing, a steel bearing plate is welded to the column base and the plate is fastened to the footing or pedestal by anchor bolts embedded in the concrete. In order to plumb columns, bolts are placed under the bearing plate and are used for ease in aligning. After the column is straight this area is grouted in with a fast-setting, high-early strength grout (*Figure 3*).

It is highly imperative that full fixity be obtained at this joint because of the critical condition of the column during the initial lift.

The joint between concrete columns and footings are identical with usual design criteria.

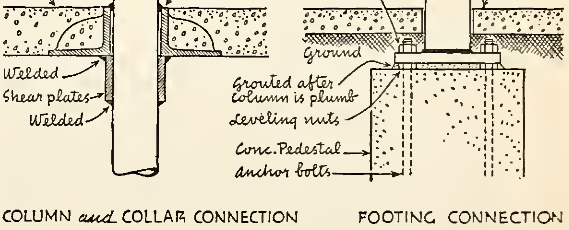
In some areas of the country it is necessary to interconnect the footings. This is also done in the usual manner.

The over-all importance in foundation work cannot be overemphasized. This is not only true in Youtz-Slick construction, but in any construction. Adequate provisions should be made for complete subsoil investigation. In lift-slab, where the entire load of the structure is usually taken by isolated footings, the importance cannot be overemphasized.

multistory and rigid frame analysis

The Youtz-Slick Method of Building Construction is not limited by any considerations to one- or two-story construction. It is entirely possible that 10 stories could be lifted and still be structurally sound and economical. The proposed lifting plan for a six-story office building is indicated by straight line diagrams (*Figure 4*). The columns are on 18-ft centers and the slab is 6½ in. Of prime concern, of course, is the stability of the columns when the total length of column from roof top to footing is 54 ft. It was found that a column formed from two angles into a box shape with a nominal 8 in. by 8 in. section was adequate in the final loaded condition. It was felt that a section larger than that would become uneconomical in the final overall cost picture. When lifting loads were analyzed, it was found that it would be impossible to lift the roof slab the entire 54 ft and fix it. However, after a few trials it was found that it would be possible to lift from approximately 29 ft and pin three slabs and hold them there while lifting and fixing the first three floors as indicated (*Figure 4*). The columns are braced adequately at the 29 ft point before lifting starts. In this instance with the column braced, the initial lift is carried out with one end fixed and the other end pinned. There is restraint against translation provided by the bracing. The roof slab is lifted and pinned to the column. This can be done by actually pinning through the column, or by welding seats on the column and sitting the slab on these seats. The same steps are followed with the fifth floor and the fourth floor. When the third floor is raised to position it is welded into position. The second and first floors are handled in the same manner as the third floor. When the first floor is complete, the lifting jack is removed and the remaining height of a column is spliced to the existing section. This splice should occur at a point on the column between one-quarter and one-half of the finished floor-to-floor height of column. After splicing, the remaining slabs are lifted and fixed in place in reverse order: roof, fifth floor, and fourth floor.

Figure 3—typical details for Youtz-Slick design.



COLUMN *and* COLLAR CONNECTION FOOTING CONNECTION

Step 1

(1) Erect column 29'
(2) Pour slabs on base slab
(3) Brace column at 29' for lifting

Step 2

(1) Raise 6,5,4, in that order and pin
(2) Raise and fix 3
(3) Raise and fix 2
(4) Raise and fix 1

Step 3

(1) Remove lifting jack from A
(2) Spike column at A to final height
(3) Replace lifting jack
(4) Place top bracing and remove intermediate bracing

Step 4

(1) Raise and fix 6
(2) Raise and fix 5
(3) Raise and fix 4
(4) Remove bracings

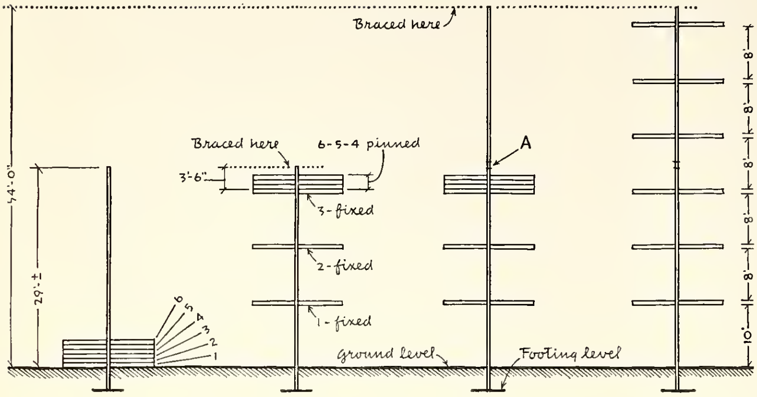


Figure 4—lift procedure for a six-story building.

During lifting, certain precautions should be taken; adequate provision against wind acting on the exposed slab edges should be maintained, particularly when the upper slabs are pinned. Adequate bracing during the initial lift should exist so that buckling does not occur at any time. It is necessary to check column strengths for all conditions of loading, including the final loaded condition.

The rigidity of multistory building is of prime importance. The wind load and the resisting stresses should be calculated for the finished building as well as during erection. The actual analysis for wind stresses is solved differently for every building because of building codes, height of building, and the width and length of building. However, certain fundamental investigations should be made. These investigations would, of course, be more critical across the short direction of the building where the wind forces are offered the large exposed surface area of the long dimension. The prime concern is the connection made between columns and footings. The bolts and welded connections should be of sufficient strength to take the added horizontal thrusts due to wind. When the building resists wind pressure it acts similar to a cantilevered truss and, of course, is held in position by the vertical load and the connections at the base. Generally, there is no danger of the building overturning, but racking of the geometrical frame must be carefully checked. The racking tendency is resisted by the stiffness of the columns, and slabs acting as a bent; hence an adequately rigid joint must be provided at the column-slab connection. This is done by welding the collar directly to the column on top and bottom, as well as the shear connector provided, as mentioned previously. In order to insure even greater rigidity, it is suggested that the reinforcing in the slab be welded to the collar wherever practical. Racking tendencies due to horizontal load can also be aided by shear walls constructed in the direction of the short dimension of the building. Partitions and exterior walls also aid in the reduction of racking; however, this resistance is variable and should not be counted on too heavily. The horizontal displacement of one story relative to the next should be considered and the columns checked to insure that they are capable of resisting this displacement.

The Youtz-Slick Lift-Slab Method is applicable to multistory construction; certain elementary precautions must be taken, of course, but the method lends itself admirably.

analysis of a typical two-story building

A two-story building erected by the Youtz-Slick Method will be analyzed in some detail. The floor-to-ceiling height of the first story is 9 ft and the floor-to-ceiling height of the second story is 8 ft 6 in. Flat-slab design will be utilized and walls are non-load bearing. The over-all dimensions of the building are 113 ft by 75 ft; column spacings are shown (*Figure 2*). The slab marked LIFT SLAB 1 (*Figure 2*) will be analyzed.

Design data:

Concrete—3,750 psi @ 28 days, unit weight 150 lb per cu ft
Steel —reinforcing bars, A.S.T.M. A-305-49
—collar steel-cast steel, S.A.E.-1030
Live load
—roof .... 20 lb/ft²
3-ply tar & gravel.......... 5½ lb/ft²
—floor .... 50 lb/ft²
Depth of slab
From A.C.I. Code........ $\frac{L}{36} = \frac{22 \times 12}{36} = 7\frac{1}{3}$ or $7\frac{1}{2}$ in.
(This value will be checked for shear and compression.)

Design procedure:

Column design:

Column height

9' 0"	1st floor to ceiling height
8' 6"	2nd floor to ceiling height
1' 2½"	thickness of roof and floor slab
2"	height above final roof elevation for jack seat
8"	distance below ground-floor elevation to top of pedestal
19' 6½"	

Maximum column dead load for lifting
Column B-2 or C-2 (*Figure 2*)
Contributing area 21' x 21'=441 ft²
$\text{Dead load} = \frac{7.5 \times 150}{12} = 93.7 \text{ lb/ft}^2$
Total load on column=441 x 93.7=41,400
plus 5% initial impact = 2,070
43,470

∴ Total load for lifting initial slab is 43,470 lb.

Column section:

Assume 5-in. standard pipe column @ 14.62 lb/ft

$I = 15.16 \text{ in.}^4$

$A = 4.3 \text{ in.}^2$

$r = 1.88$

$l = 19' \, 6\tfrac{1}{2}'' = 234.5 \text{ in.}$

$$\frac{l}{r} = \frac{234.5 \times 2}{1.88} = 250$$

Since the $\frac{l}{r}$ ratio taken as a free-standing column is high, the Euler equation for this column condition is used to determine the adequacy of the column section assumed:

$$P \text{ (critical)} = \frac{\pi^2 E\, I}{(21)^2} = \frac{\pi^2 \times 29 \times 10^6 \times 15.16}{4(234.5)(234.5)} = 19{,}600 \text{ lb}$$

This section is obviously unsatisfactory because the critical buckling load is indicated to be 19,600 and the lifted load is 43,700 lb.

Assume 8-in. standard pipe column @ 24.7 lb/ft

$I = 63.35 \text{ in.}^4$

$A = 7.265 \text{ in.}^2$

$r = 2.95$

$l = 19' \, 6\tfrac{1}{2}'' = 234.5 \text{ in.}$

$$\frac{l}{r} = \frac{234.5 \times 2}{2.95} = 159$$

Thus

$$P \text{ (critical)} = \frac{\pi^2 \times 29 \times 10^6 \times 63.35}{4(234.5)(234.5)} = 83{,}500 \text{ lb}$$

Thus, the critical buckling load on this section is 83,500 lb. A factor of safety against buckling of $\frac{83.500}{43{,}470} = 1.88$ exists, since the height of lift is small and wind thrusts on the slab edge is low, this section will be used.

The anchoring of the column to the footing is shown (*Figure 3*). The bolts and weld are designed according to conventional methods. The column should then be checked in the final loaded condition:

Load. .roof	—dead load	41,400
	live load	11,050
2nd floor	—dead load	41,400
	live load	22,100
		115,950 lb

Length of free span = 116 in.

$$\frac{l}{r} = \frac{116}{2.95} = 39.4$$

$$\frac{P}{A} = 17{,}000 - .485 \frac{(116)^2}{(2.95)^2}$$

$$\frac{P}{A} = 16{,}230 \text{ psi allowable}$$

$$\frac{P}{A} = \frac{115{,}950}{7.265} = 16{,}000 \text{ psi actual}$$

Thus, this section is satisfactory in the final loaded condition.

Shear analysis at the collar:

Allowable shear = .025 f′c = 93.5 psi

Maximum reaction at second floor = 63,500

Effective depth of slab = $7\tfrac{1}{2} - 1\tfrac{1}{2} = 6''$

Assume 20″ x 20″ square collar

Thus $v = \dfrac{V}{hjd}$ $\quad V = 63{,}500$

$h = 4(20 + 2(6)) = 128''$

$j = .875$

$d = 6''$

$$v = \frac{63.500}{128 \times 6 \times .875} = 94 \text{ psi}$$

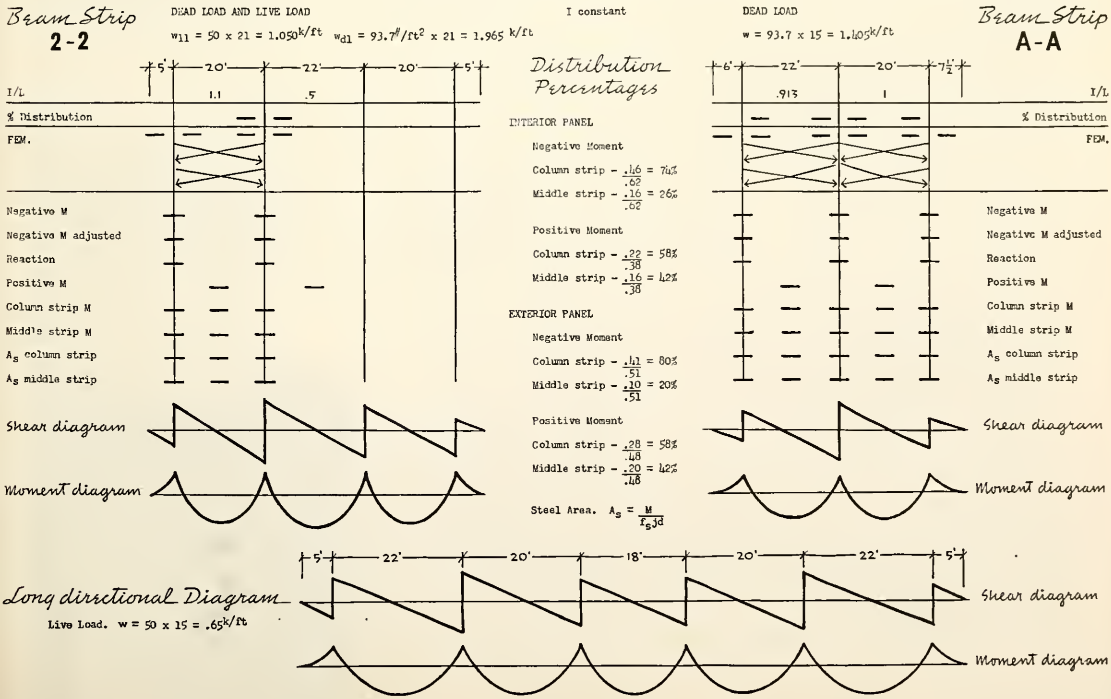


Figure 5—design sheet.

Thus, a collar with a base plate 20 in. by 20 in. will be used. If a concrete with less strength was used it would be necessary to increase plate size or increase the depth of slab. It would also be possible to design stirrups to take the added shear if it was so desired.

design of the reinforcing steel

As outlined in the general discussion of flat slabs, the slab is divided into individual two-way interlocking beam strips as shown (*Figure 2*). In this slab, beam 2-2 at the internal section of the slab will be analyzed along with beam A-A, an exterior beam strip.

The various loading conditions analyzed using Moment Distribution and taking full account of symmetry are indicated (*Figure 5*). As shown, the conditions analyzed include investigation of dead load, and following the provisions of the A.C.I. Building Code, the live load condition with all panels loaded simultaneously. No account is made in this analysis for the added stiffness contributed by the lifting collar at the supports; however, many designers may take this stiffness into account. The critical section for positive moments is taken at the center of the spans; the critical sections for the negative moments is taken at the column line with a reduction in negative moment allowed, based on a critical section at the center of gravity of the lifting collar.

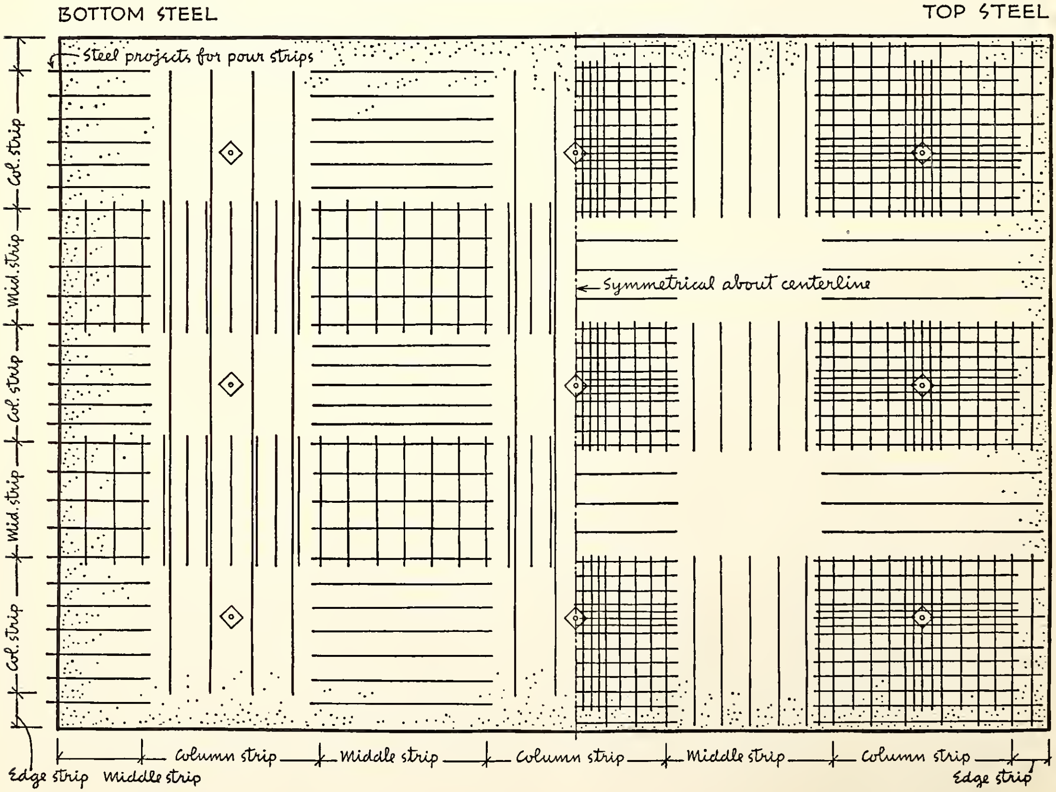
After the critical moments are obtained, they are divided by percentages of total moment into column strips and middle strips according to the ratio of specified coefficients in the A.C.I. Building Code. The areas of steel are then obtained and divided into the reinforcing bars required. It should be pointed out that the slab is designed as a complete unit in the long direction for the live-load condition. This is due to the fact that the two lift-slabs are joined by a moment joint, and the resulting continuous span must include steel to resist positive live-load moment at this point. Steel in the column strip in line with the collar is carried continuously across the collar.

The compressive stress and the bond stress developed in the concrete is then determined. It is realized that neither of these values obtained are true values because no provision has been made for the biaxial bending condition that actually exists.

Openings in the slab may be provided if provision is made for the total positive and negative moments in that panel. It is suggested that openings should not be cut in the slab in the immediate area of the column.

The remaining design of the structure is then completed and a Youtz-Slick building is completely designed.

Figure 6—typical slab-steel layout for lift slab.

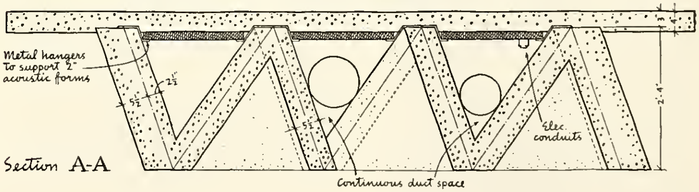


Three-Dimensional Floor System

Undoubtedly the most interesting structural innovation of the Yale Design Laboratory Building (an addition to the existing Art Gallery) will be the new three-dimensional floor-ceiling system conceived by Louis Kahn—Philadelphia architect and faculty member of the Department of Architecture at Yale. Kahn's philosophy of structure holds that a building material should be designed to take maximum advantage of all its physical properties. Thus, when all integral elements are capable of working at capacity, the resultant form is the correct expression for a given material. Kahn visualizes a concrete floor-ceiling system for a design laboratory as working most efficiently when cast in a tetrahedron-type design (*reflected ceiling plan and cross section below*). Such a design, which will be constructed for the first time, has already been developed and load tested at New Haven.

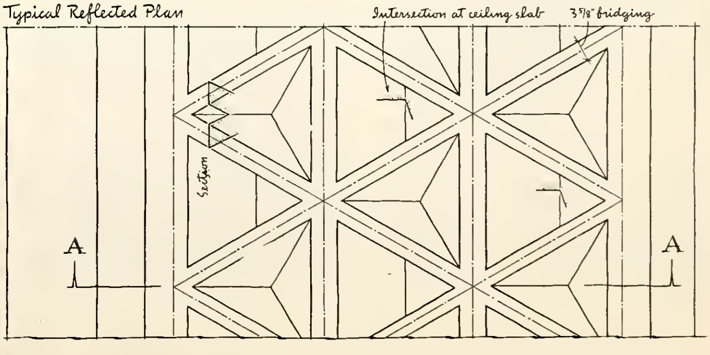
As the local building code requires that some sort of a beam system be used for all floors, an exact translation of Kahn's original conception was not possible and the longitudinal ribs of the tetrahedron design somewhat act as beams. A special full-scale test model of the new span was erected to satisfy the New Haven Building Department that the system would meet minimum safety requirements (*photo, below left*). The design load for the model was: 100 psf live load and 175 psf dead load (including 15 psf for floor surfacing materials). The ribs were poured to a depth of approximately 2 ft 4 in.; over the ribs was placed a 2-in. layer of cement-bonded wood-fiber panels and a 4-in. slab of concrete—the panels bonding automatically with the concrete. The bottom of each primary rib contains a 1¼-in. square bar while a ⅝-in. round was placed in each secondary member of the pattern. 3000 psi concrete was specified for the floor-ceiling and 3750 for the columns. Bags weighted with crushed stone were placed atop the slab until an amount equal to twice the live load had been attained. Although 0.70-in. deflection would have been permissible for the 40-ft span, the actual recorded deflection at the center was only 0.15 in.

Kahn calls this development three-dimensional construction, as the ceiling forms a pattern that is in contrast to the traditional flat-surface type of ceiling. Among its advantages are: all ductwork and conduit can be easily placed within the ceiling without being readily apparent and without effecting the strength of the system whatsoever; lighting elements can be placed in the tetrahedrons so that when viewed from any other location than immediately below, direct light from the source is cut off by the ribs; good acoustical conditions are inherent.



Design Laboratory, Yale University, New Haven, Connecticut: Louis Kahn and Douglas Orr, Associated Architects; Henry A. Pfisterer, Consulting Engineer. Full-scale model of three-dimensional floor-ceiling system undergoes load test (below). *With 215 psf (twice live load) placed on the floor, the measured deflection at center of the 40-ft span was 0.15 in.*

Reflected ceiling plan and cross section (right) *illustrate tetrahedron pattern.*



Unit Building System

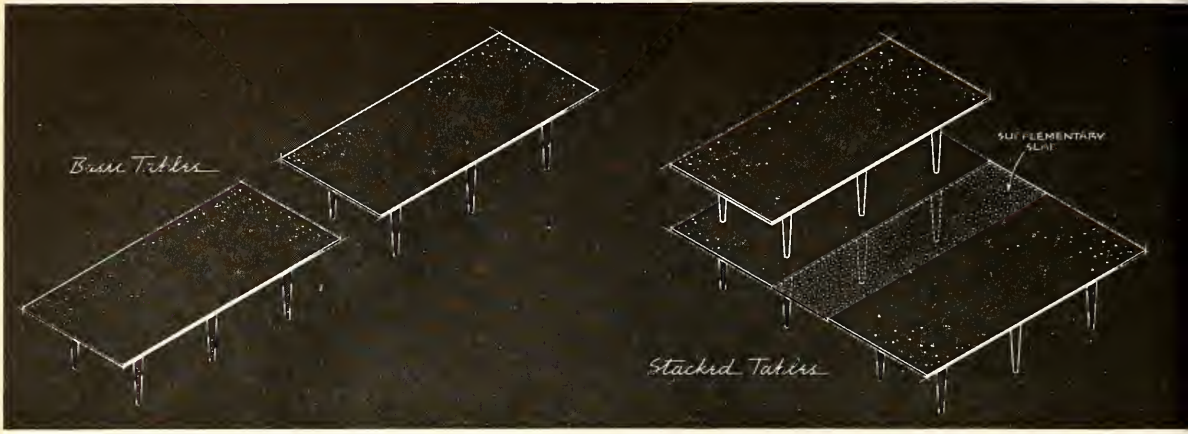


Figure 1—sketches show basic relationship of unit buildings (tables). This construction system which produces flexible, low-cost buildings can be applied to any type of structure.

The unit building system of reinforced concrete construction is ideally suited to industrial buildings where repetitive elements are generally desired. Utilizing a cantilevered, reinforced - concrete - plate slab supported on "hinged" reinforced columns, this system offers excellent economies in construction costs. A parking garage in New Orleans was recently completed at a total cost of $2.00 per square foot; this figure indicates the savings that can be realized when the method is used for industrial building. Laurence G. Farrant, Miami consulting engineer who developed this construction method, reports that this system was selected for the parking garage because of its low cost and the smooth unobstructed ceilings that it provided. (Farrant was associated with New Orleans Architects and Engineers, Diboll-Kessells.)

In simple terms, the unit building system might be likened to a series of tables *(Figure 1)* whose tops extend well beyond the legs on all sides. These tables, identical in size, form the unit bays of the building; additional tables, stacked on top, form the succeeding stories. In practice, space is left between the cantilevered floor slabs of each unit to provide a logical and efficient location for stairwells, elevator shafts, and other vertical access.

design and construction

In the design of the unit building, the use of a cantilevered floor slab results in a slab of considerably less average depth than that required for a continuous monolithic structure. In the New Orleans garage *(Figure 2)*, the average thickness for the cantilevered slab was 7½ inches as against a 12½-inch thickness that would have been required for a slab designed on a continuous monolithic basis. In spite of this reduction in slab thickness, a saving of approximately 30 percent in reinforcing steel was realized because loading conditions could be determined accurately and the bars cut off where they were no longer required.

The fact that unit buildings are repeated, saves considerable time in cutting and placing of reinforcing steel, since the pattern is identical for units. The unit system also makes it possible to erect forms and pour concrete on a scheduled basis, to permit a maximum re-use of standard forms. Construction progresses on a unit basis because each bay is an independent element, hence continuous pouring operations are not necessary.

Tapered columns, not a requirement for this system, can be used to advantage to minimize the size of the supports at the building use level, yet provide the bulk necessary at the critical portions of the columns to take care of the greater moment developed by the cantilever.

The "hinge" or socket at the bottom of the typical column eliminates a transmittal of the bending moment to the column and the unit building below. In the New Orleans garage, each column contains a cold-rolled steel shaft which rests in a socket formed in the top of the column below. Although not an essential element of this system, the steel shafts were provided to carry future loads; two additional floors of normal commercial occupancy will be constructed above the present garage. The reinforcing bars of the column *(Figure 3)* are welded to this shaft and the axial load is transferred from the column to the shaft

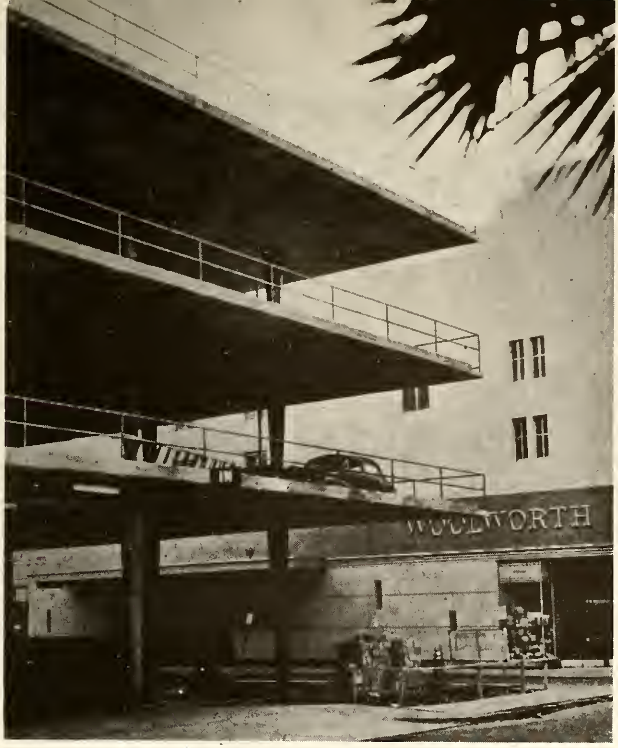
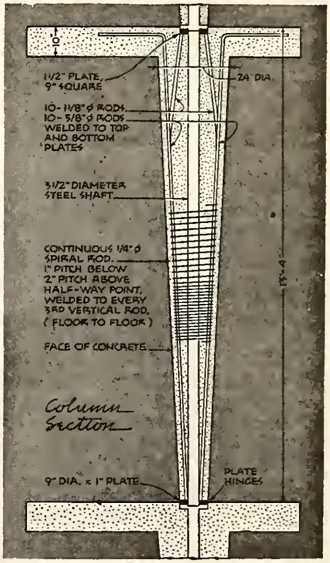


Figure 2—one corner of the three-story New Orleans parking garage *(left)* which was constructed at a cost of $400 per car exclusive of property values.

Figure 3—section through typical tapered column *(below)*. The hinge at the base allows the transmittal of bending moment from one unit building to another.


10"
1 1/2" PLATE, 9" SQUARE
24" DIA.
10- 1 1/8" ϕ RODS
10- 5/8" ϕ RODS
WELDED TO TOP AND BOTTOM PLATES
3 1/2" DIAMETER STEEL SHAFT
CONTINUOUS 1/4" ϕ SPIRAL ROD. 1" PITCH BELOW 2" PITCH ABOVE HALF-WAY POINT, WELDED TO EVERY 3RD VERTICAL ROD. (FLOOR TO FLOOR)
FACE OF CONCRETE
13'-4"
Column Section
9" DIA. × 1" PLATE
PLATE HINGES

and from the shaft to the column by virtue of this design. The relative stiffness of the column and its integral connection with the slab at the head result in the efficiency of the hinge action in the socket at the base. Pea gravel was used to assure placement and compaction of concrete in the column reinforcement; such a workability had to be produced together with a strength of 5000 psi. This combination of requirements was achieved at a minimum cost for both materials and finishing by the following mix design for one cubic yard of concrete: portland cement, 6.92 sacks; sand, 1169 pounds; gravel, 1848 pounds dry; cement dispersing agent, 3.46 pounds; entrained air, 4.30 percent; total amount of water, 37 gallons. When forms were removed, paint was applied to the columns without the additional cost of finishing. Entrainment of air, with no loss in strength, provided a resistance to weathering necessary for an open structure of this type.

The independence of each unit building assures a freedom of movement through natural expansion joints occurring at the juncture between units. This independence also minimizes the effects of differential movement due to foundation settlement, bombing, or similar causes. Analysis of the unit design is generally complex and many assumption must be made.

From the standpoint of architectural planning, ideal unit dimensions depend on use requirements, floor loads, and the limitations resulting from developing identical unit buildings. In the New Orleans building, columns were spaced alternately on 16- and 32-foot centers to obtain economy in slab thickness and to meet, at the same time, the space requirements of the building.

advantages

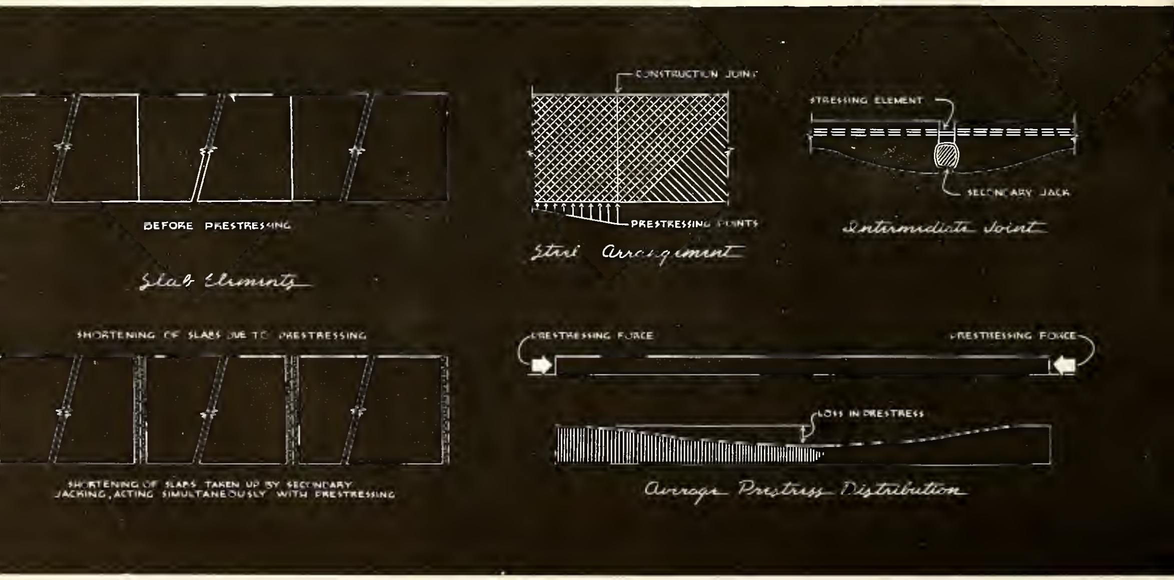
The unit building system of construction offers a number of advantages in buildings designed for industrial purposes that are not readily obtained through conventional methods. Low building costs and the minimum use of critical materials makes the use of this system particularly attractive in light of present-day conditions. The elimination of any need for load-bearing walls gives a desirable flexibility to planning arrangements and future partition changes.

Prestressed-Concrete Floor Construction

A major problem confronting airport designers has been to develop a slab for hangar floors (and runways) strong enough to support heavy loads, yet flexible enough to follow the local deformations of the supporting soil. An equally important problem for airport owners has been the costly maintenance of construction and expansion joints. The Preload Company, Inc. (New York), a firm of engineers specializing in prestressed design, believes that it has found a solution for both problems in a new-type, thin, prestressed slab which minimizes, if not altogether eliminates, expansion joints. This company's proposed solution utilizes a 4-in. slab prestressed by jacking in two stages. Their contention is that due to its extreme flexibility and high compressive prestress, the slab will be capable of following the uneven deformations of the soil and sub-base under load and will recover to be free from cracks after removal of the load. Such a slab, designed to be free from cracks normally leading to the deterioration of heavier reinforced concrete mats, will require minimum maintenance and will have a long life expectancy.

By this method, the prestressing bars, first coated to prevent bond with the concrete, are placed over the subgrade in a two-way diagonal pattern (*illustrated below*). The concrete is then poured and the bars allowed to extend slightly beyond the edge of the concrete. After curing, the bars are stressed and anchored; because of their diagonal pattern, they force the slab into compression both longitudinally and transversely. Due to the extreme length of the slab, however, this force is insufficient, as much of the compression is absorbed by friction on the sub-base as the slab attempts to shorten elastically under the stress.

Here is the unique feature of this concept. To overcome the above loss and to maintain the slab in its original overall length, flat jacks are placed in convenient intermediate transverse construction joints and expanded simultaneously with the stressing of the diagonal bars. This confines the elastic shortening to the tranverse construction joints. The joints are then packed with mortar and after hardening of the mortar, the jacks are released. The action of the bars then keeps the joints under compression. As a result, one has, in effect, a completely monolithic slab without expansion or construction joints as such.



Sketches indicate slabs before and after prestressing, diagonal pattern of bars, location of secondary jack, and diagram of average prestress distribution.

Prestressed Concrete Today

BY J. J. CLOSNER AND CEDRIC STAINER*

Prestressed concrete is to many minds one of the 20th Century's most important additions to our structural resources. Brought into being by the incorporation of a dynamic steel musculature into the inert body of concrete to give this ancient construction material tensile strength comparable to its intrinsic compressive strength, prestressing has established its merit on a world-wide proving ground.

In the five years since PROGRESSIVE ARCHITECTURE last reported comprehensively on this subject *(October 1949)*, prestressed concrete has gained more ground than in the entire quarter-century since it became a construction reality. Its advance has been three-front—in research development, in applications, and as a consequence of both in public acceptance.

Certainly the current defense program has helped to spotlight the savings of materials inherent in prestressed-concrete design. There are vivid examples. Only 8.08 tons of steel were required to construct the six prestressed-concrete floor girders for a new building at Manhattanville College of the Sacred Heart, at Purchase, New York, whereas the original design in structural steel had called for 72 tons. *(Figure 1)*. A 5,000,000-gal prestressed-concrete water-storage reservoir is now being built at Richmond, Virginia, with only 210,000 lb of steel, although the city had actually obtained a 1,000,000-lb allocation for the project from NPA.

It is a conservative estimate that a structural member in prestressed concrete may be built with only half the concrete and a quarter of the steel required for a corresponding member in reinforced concrete; in comparison with structural steel, the saving in steel is even greater.

These savings of materials are only a fragment of the picture. They produce in turn savings in deadweight, which means a substantial reduction in foundation costs. Depth reduction of the main carrying members brings savings in over-all building height. Longer-span construction made possible through prestressed design results in maximum space utilization.

In addition, prestressed concrete makes definite esthetic contributions. Not only does it allow lighter-looking structures, with far lower depth-to-span ratios than are obtainable with reinforced concrete, but it also permits structural designs that are precluded with other forms of construction.

Scientifically, prestressed concrete has attained world significance. Within 18 months after the first United States Conference on Prestressed Concrete was held at M.I.T. *(August 1951)*, the new medium was an important subject at numerous technical gatherings throughout the country.

Its stature is documented with equal weight in the roster of users and uses. In this country, alone, it is being employed in every section by private enterprise and by all levels of government construction, on a rapidly increasing scale. This is equally true abroad. In England, a recently published report of the works directors of the Admiralty, the Air Ministry, the War Office, and the Ministry of Works on economy of building materials, recommends the use of prestressed concrete in almost every conceivable form of construction.

Similarly, our own President's Materials Policy Commission, in its notable report entitled "Resources for Freedom," has stated the belief that prestressed concrete "will be particularly successful in replacing reinforced concrete."

development of prestressed concrete

This article does not pretend to cite more than a partial list of structures, techniques, even products themselves, which prestressing has created.

In bridges the Federal government is using a prestressed concrete structure to carry a main highway across the spillway of the monumental Garrison Dam, near Bismarck, North Dakota. Florida is using prestressed concrete for the 3½ miles of trestles of the huge Pinellas-Manatee Crossing over Tampa Bay. Philadelphia built its distinguished Walnut Lane Bridge across a Fairmount Park ravine in prestressed concrete. New York City is using it to replace the immense North River pier destroyed by fire in 1947. Massachusetts has let contracts for the construction of four highway bridges at Newbury and Newburyport, in what is literally a special project to ascertain the most economical and suitable methods of prestressed design for bridges in that state.

In buildings, designers are finding prestressed concrete an effective solution of their framing problems. This is especially true of buildings requiring large clear spans for such areas as school gymnasiums and auditoriums. School design frequently calls for spans brought well into the range of real economy through prestressing.

The Bishop DuBourg School (Murphy & Mackey, Architects) at St. Louis, Missouri, designed in the prestressing system of Eugene Freyssinet, noted French engineer whose studies of plastic flow and shrinkage in concrete were a major factor in the development of the medium, uses 94 ft roof beams to span the gymnasium. The girders of the Manhattanville College building, (Eggers & Higgins, Architects) first major floor system in the United States to be supported by prestressed concrete, are 65 ft long and less than eight percent deeper than they would have been in structural steel *(Figure 1)*.

Europe, still ahead of us numerically in linear structures, presents perhaps the only prestressed-concrete multistory construction. The most recent developments in this field are the work of Dr. Fritz Leonhardt, German bridge designer who is the inventor of the first practical prestressing method which achieves continuity in structures. A Leonhardt bridge is shown *(Figure 2)*; his methods and techniques will be described below.

England has developed a rewarding application of prestressed concrete in combination with shell-roof construction

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**Vice-President and Acting Chief Engineer, respectively, The Preload Company, Inc., New York, New York* which has captured the imagination of British architects to the extent that some 500 shell-roofed structures have been built there since World War II. A striking example is a 300-ft-long Bournemouth bus-terminal garage with a roof formed by nine thin concrete shells resting on prestressed edge beams which span 150 ft and provide a clear floor space of 45,000 sq ft *(Figure 3)*.

In the circular field, the prestressed domes, which The Preload Company, New York, developed to roof many of the tanks it has designed, may provide a fertile ground for exploration by architects of sports arenas, theaters, and other structures demanding large clear spans, unobstructed views, and maximum availability of good seats. These domes, prestressed at the abutment ring and varying in thickness from 2 in. for a 50-ft diameter to 6 in. for a 250-ft diameter, are spherical shells with a rise of only one-eighth their diameter. They are built without roof trusses or interior supports, the abutment ring being carried by the side walls or by columns at the periphery of the dome. Only through prestressing may such domes be built without dangerous deflections when the falsework is removed. And they require only 4-½ to 5 lb of steel of all classes per sq ft of dome area.

In Canada, the city of Sherbrooke, Quebec, is building a 4000-seat municipal stadium with prestressed concrete for its frame, seating slabs, and 25-ft cantilever roof. *(Figure 4)*. This structure is being built with only 12.75 lb of steel of all classes and .15 cu yd of concrete per seat.

In America, the achievement of mass production of prestressed concrete blocks combines with the development of an integrated block system for area prestressing to provide a major construction efficiency. This permits the designer to develop a standard modular relationship for different bay sizes and enables the contractor to order factory-made blocks for on-site assembly and to erect floors and roofs without heavy lifting equipment.

Prestressed concrete has made all these great strides despite two major handicaps —one technological, the other the result of professional practices within the industry itself.

The technological handicap was that the inherent economies of the medium were offset by the cost of labor for placing, stressing, and anchoring the tensioning units. This has now been largely overcome. In the opinion of many constructors, the works of Leonhardt and Donovan H. Lee, London consulting engineer, are among the most notable recent achievements in this direction.

Leonhardt's method of continuous prestressed bridge construction is based on concentrating the very large prestressing forces required in bridges so that a contractor can prestress an entire structure in a single operation instead of wire by wire, or cable by cable, as other systems necessitate.

The late Dean Peabody Jr., professor of architecture at Harvard University, rated the importance of continuity as follows: "Prestressed concrete design is in its infancy until the engineers in the field and in the office can solve the $64-question of constructing economical continuous beams."

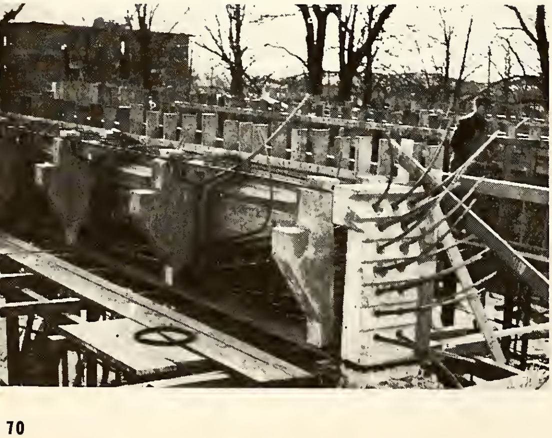
Continuity makes possible a saving of approximately 25 percent of the steel required for simply-supported prestressed beams. Leonhardt's techniques save half the man hours per ton of prestressing steel which other systems require to place, tension, and grout the cables for an entire structure. Thus, combining the reduced material and labor factors, it is seen that a Leonhardt structure may be prestressed in less than 40 percent of the man hours required by other systems using wires or cables as the tendons of prestressed concrete.

Lee's contribution is in the tendons themselves. In collaboration with McCall & Co., Ltd., British steel producer, he developed a new kind of steel bar of extremely high strength, together with anchorage, as the tensioning unit of prestressed concrete (*Figure 6*).

Until its advent, wire was the only form of steel capable of the sustained high stresses essential for prestressing concrete. This bar is the only steel of comparatively large diameter which approximates the high tensile strength of wire. A 1-⅛-in. bar does the work of 22 wires each .196 in. diameter, a standard size in prestressing. One simplified bar anchorage supplants a multitude of intricate wire anchorages. Compared with wire, the use of this bar produces labor savings which, at prevailing wage rates for United States iron workers, may often exceed the entire cost of the prestressing material.

new operating concepts

In the matter of professional practices, for years every owner or builder wishing to erect a structure in prestressed design was confronted by a barrier of patents and proprietary systems. The resultant discouragement of numerous architects and engineers from exploring the potentialities of



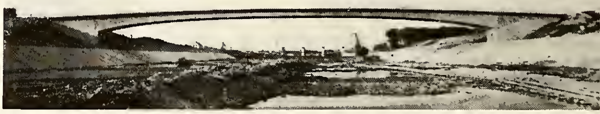


Figure 2—world's largest concrete-box girder span, across Neckar Canal near Heilbronn, Germany (above). *Completed in 1950, main span of 312 ft has a 1:56 depth-to-span ratio.*

Figure 1—progress photo (left) *shows one of six floor girders at Manhattanville College; twenty-two cables have been placed and member is ready for secondary reinforcement. Each cable, made of 12 high-tensile-steel galvanized .196 in. diameter wires, receives a pull of 26 tons during prestressing.*

the new medium was attested by no less an authority than Rear Admiral J. F. Jelley, Chief of the United States Navy Bureau of Yards and Docks, when he said at the M.I.T. conference in 1951: "We do have one serious handicap in prestressing. In the interest of obtaining adequate competition for our work, we are loath to use patented material. I find that many of the devices and methods now involved in prestressing are patented. The Navy will not make wide use of patented materials unless they are freely available to all contractors on an equal basis."

The Preload Company can lay reasonable claim to some of the credit for curing this ill. In its first 17 years this organization, along with others in the field, designed prestressed structures, under license of its patents, for its domestic construction subsidiaries and its foreign licensees. Ultimately it saw that the new medium had reached the stage at which public interest and profitable operation demanded the availability of broad, fundamental developments to the construction world at large on a normal competitive basis. Its opinion was sustained by the findings of a nationally known firm of management consultants, McKinsey & Co., which it retained to make an objective survey of the prestressing industry.

As a result, The Preload Company a year ago recast its entire operation and established itself as an independent firm of consulting engineers devoted exclusively to the design of prestressed structures—designing in any system best suited to the project at hand, serving any client who wishes to retain it, and using unrestricted prestressing systems of its own as a control on competing proprietary systems.

The company, in choosing this course, has sought to open up the entire field of prestressed concrete as a basic medium of structural design in which architects, engineers, and contractors everywhere can work as familiarly and unrestrictedly as they do in reinforced concrete and structural steel.

Leonhardt made Preload the exclusive licensee under his system for North America, Cuba, Great Britain, France, and South Africa largely because of its new policy and its willingness to relicense its clients at the cost of its own nominal royalty payments to him. Preload's efforts also led a group of American and Canadian business men to form the Stressteel Corporation to manufacture the bar and anchorage tensioning units under license from the Lee-McCall system proprietors and sell them on this continent on a price-list basis. Leonhardt's bridge-building methods are described here in some detail because his "Leoba" system for prestressing in multistory construction is largely derived from them.

A Leonhardt bridge starts with the construction, side by side on the abutment at each end, of semicylindrical blocks of reinforced concrete about which the prestressing cables are looped and anchored. The blocks rest on prepared basis for subsequent movement, although in small bridges the blocks at one end are stationary.

Rectangular, liquid-tight troughs to house the cables are placed horizontally throughout the length of the structure and supported on stirrups to provide the desired trajectory for continuity over supports. A mechanical dolly places the cables in the troughs. Friction along the cables during tensioning is overcome by developing a polygonal rather than a smoothly curving trajectory and placing paraffin-coated sliding plates between the cables and the trough lid or bottom at each direction-changing point.

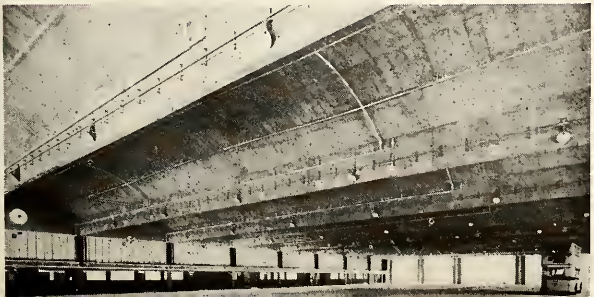
Recesses are provided for the installation of hydraulic prestressing jacks. When the concrete has been poured and has achieved the desired strength, the jacks are actuated to bear against the main-section concrete and force back the end blocks until the cables anchored around them have been elongated the desired extent. The resultant gaps between the main section concrete and the end blocks are then filled with concrete to maintain the elongation when the jacks are removed, and the metal troughs are filled with grout under pressure to provide continuous bond and protection for the prestressing elements. When completed, the entire structure is a solid mass of compressed concrete and tensioned steel.

In his multistory work, Leonhardt prestresses a beam with 12 wires arranged in two horizontal layers in a flat sheath instead of in the usual round cable, which enables him to achieve continuity over several supports without appreciable variation of the stress due to friction. The wires are attached to a fixed anchor at one end and at the other are anchored around a forged-steel plug which has a threaded recess for the insertion of a jacking bar.

After placement and curing of the concrete, the jacking end of the beam is covered by a temporary steel plate through an opening in which the jacking bar is screwed into the plug. The bar is then connected to a hydraulic jack which draws the anchor plug back until the wires have been elongated as required. A nut on the bar is run down to bear against the plate and maintain elongation when the jack is disconnected. Grout is then pumped through the plate into the plug recess and along the entire length of the wires, providing not only a permanent bearing surface for the anchor plug when the plate and bar are removed, but also permanent bonding for the wires.

Using this system, Leonhardt has erected a six-story paper plant at Heidenheim (*Figure 7*) and a four-story garage at Fellbach *(both were constructed in Germany).* The paper plant has a 63-ft span between two rows of columns and a 15-ft cantilever beyond each column line. The main girders are haunched at the supports and are

Figure 3—bus-terminal garage, Bournemouth, England. Nine concrete shells 2½ in. thick are supported by prestressed edge beams spanning 150 ft. Edge beams were prestressed by the Magnel-Blaton system with three parabolic cables; the final prestressing force applied was 438 tons.



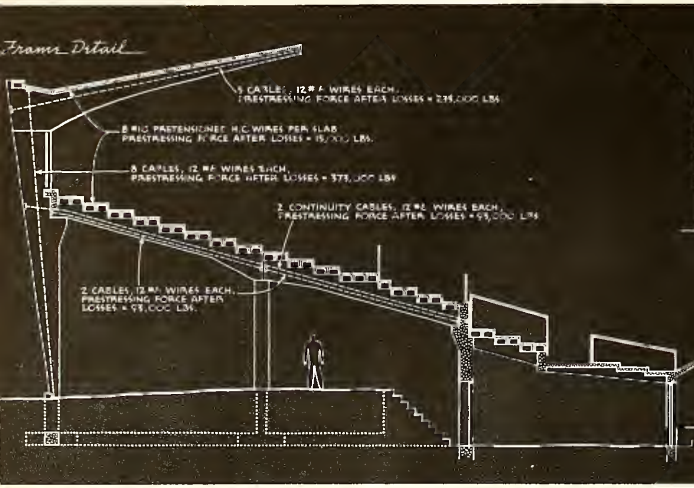

Frame Detail
5 CABLES, 12 #6 WIRES EACH, PRESTRESSING FORCE AFTER LOSSES = 235,000 LBS.
8 #10 PRETENSIONED H.C. WIRES PER SLAB PRESTRESSING FORCE AFTER LOSSES = 15,000 LBS.
8 CABLES, 12 #6 WIRES EACH, PRESTRESSING FORCE AFTER LOSSES = 373,000 LBS
2 CONTINUITY CABLES, 12 #6 WIRES EACH, PRESTRESSING FORCE AFTER LOSSES = 93,000 LBS
2 CABLES, 12 #6 WIRES EACH, PRESTRESSING FORCE AFTER LOSSES = 93,000 LBS.

Figure 4—municipal stadium (above left) *in Sherbrooke, Quebec, Canada, is a unique example of a prestressed-concrete frame: supporting column, roof slab, frame, and seating slab were all prestressed. Supporting column and roof slab were prestressed together, making a two-piece monolift.*

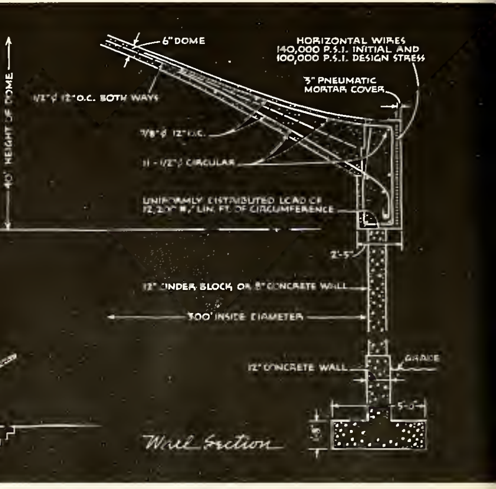

6" DOME
HORIZONTAL WIRES 140,000 P.S.I. INITIAL AND 100,000 P.S.I. DESIGN STRESS
3" PNEUMATIC MORTAR COVER
40' HEIGHT OF DOME
1/2"ϕ 12" O.C. BOTH WAYS
7/8"ϕ 12" O.C.
11 - 1/2"ϕ CIRCULAR
UNIFORMLY DISTRIBUTED LOAD OF 12,200 #/LIN. FT. OF CIRCUMFERENCE
2'-5"
12" CINDER BLOCK OR 8" CONCRETE WALL
300' INSIDE DIAMETER
12" CONCRETE WALL
GRADE
5'-0"
Wall Section

Figure 5—section (above right) *shows possible prestressed-concrete solution for a 300 ft diameter sports arena with dome-shaped roof. The 6-in. thick spherical shell can be restrained at the edges by a prestressed abutment ring, 2 ft 2 in. thick and 6 ft deep, resting on a 12 in. concrete-block wall.*

2 ft 9 in. deep at midspan, a depth-to-span ratio of 1:23. The spacing between the girders is 22 ft 6 in. and the floor load is 154 psf. The garage involves spans of 36 ft 6 in. with a girder depth of 2 ft 7 in. at midspan.

Unlike the Leonhardt methods, the Lee-devised bar-tensioning units already have been practically demonstrated in the United States although they will not be in production domestically until early this year.

The material was imported from Britain to put the Tampa Bay bridge trestles in tension, and only by its use could prestressed design have competed successfully with designs in reinforced concrete (*Figure 8*). Only 6534 tensioning units are needed for the three-and-a-half miles of trestles. Had .192-in. wire been used, as provided in a comparison-alternative design, it would have necessitated the placing, stressing, and anchorage of 116,000 individual strands, which would have cost an estimated $225,000 more than the bar tensioning.

These bars are of a special alloy steel treated by a cold-working process which endows them with amazingly high physical properties. At each end is a specially-designed, long tapered thread engaging with a matching nut, which develops 100 percent of the 145,000 psi guaranteed strength of the bar and provides positive end anchorage. The bar is elongated with a hydraulic jack and the nut is run down to bear against a steel plate which distributes the tremendous terminal forces at a safe unit loading at the extremities of the prestressed-concrete member (*Figure 8*). The bars are made in diameters from ½ in. to 1-⅛ in. and in lengths up to 80 ft; couplers that develop the full guaranteed ultimate strength of the bars are used for greater lengths.

These units are by far the simplest of all the tensioning material used and may be installed before or after the pouring of the concrete and for bonded or unbonded prestressing. Naturally there is considerable economy in coating the bars to prevent bond and placing them in the concrete before pouring, just as is done with ordinary reinforcing steel, but this does not provide as much resistance to unexpected overloads as when the steel is bonded to the concrete by pressure-grouting after prestressing. For this reason, leading prestressed-concrete designers generally use unbonded prestressing for structures on which no overload is anticipated, such as certain roof systems, but utilize the higher safety factor of bond for structures such as heavy-duty bridges, future uses of which may exceed the design loads.

There is a host of construction uses to which Stressteel bars may be put with real economy and efficiency, and building frames constitute one of their most advantageous applications, especially in the framing of structures in which unobstructed space is a necessity.

Prestressing with Stressteel is particularly economical when girders 40 ft or longer are required to frame over such areas. In reinforced concrete the girders would have to be cast in place, using heavy and expensive falsework, but with Stressteel-tensioned concrete the weight is so greatly reduced that they may be precast and prestressed on the ground and lifted into place by cranes normally employed on jobs of this type.

architectural engineering considerations

Many architects and engineers as yet uninitiated in prestressing frequently inquire what types of structures may be designed in prestressed concrete and what is the "best" system to use.

Any structure which may be designed in structural steel or reinforced concrete may also be designed in prestressed concrete, and frequently at a saving in cost—especially when a metallic skeleton must be encased in concrete for enhanced appearance or greater fire resistance.

In the same way that designers have long considered reinforced concrete and structural steel as obvious alternatives for the design of any structure, they must now regard prestressed concrete as a third alternative.

There is no rule-of-thumb that states one structure must be built in this material and another structure in that. Every undertaking is attended by its own specific circumstances. Nor is there a set rule for the selection of any particular method by which to build in prestressed concrete itself. Pretensioning systems, in which the stressing member is tensioned before the concrete is poured around it, differ mainly in their use of different sizes of wire or strand. Post-tensioning systems, apart from the Leonhardt looped-cable and the Preload circular wire-winding methods which employ no special anchorage unit, differ mainly in their use of different bars, wires or strands, and different types of anchorage units. Yet the cost per pound of prestressing steel differs considerably from system to system.

Why not, then, always use the raw material that costs the least? The answer is that the method which employs the least expensive material may not be suitable for the structure at hand or, though suitable, may entail a far higher labor cost for installation of the material.

For example, the Leonhardt looped-cable method costs less than others per pound of prestressing steel in place, but it is applicable only to cast-in-place work; for certain structures this method is more expensive than precasting. On the other hand, anchored stranded cables may in themselves appear costlier than other materials; for certain types of construction, however, they bring compensating economies because their on-site labor costs are low.

The prestressing steel may be in any of the following forms:

(1) Individual wires held by bond alone (pretensioning).

(2) Individual strands held by bond alone (pretensioning).

(3) Wires grouped to form cables and held by a special anchorage and usually by bond as well.

(4) Individual strands held by special end anchorages and sometimes by bond as well.

(5) Strands grouped to form large looped cables held by the loops and usually by bond as well.

(6) High-strength alloy bars with special anchorages and usually bond as well.

It is by no means necessary to prestress every part of a structure. Obviously it is disadvantageous to prestress structural elements which are entirely in compression. Columns, for example, need be prestressed only when they are subjected to sufficient bending to cause tension, or they may sometimes be prestressed to tie them to other parts of the structure by means of the tensioning units.

Where simple spans are involved it is almost always advantageous to prestress girders and beams. If the spans are less than 25 ft and the loads do not exceed 200 psf, prestressing is usually economical when factory-made, pretensioned beams or joists are available in the locality. In this span and load range, depth-to-span ratios of 1:30 to 1:35 are common when the joists are close together, approximately 2 ft on center for a 50 psf loading or side by side for a 200 psf loading.

When spans exceed 25 ft and conventional girder and slab construction is used, the depth-to-span ratios in prestressed concrete compare favorably with those obtained by use of encased steel.

For cast-in-place construction it is desirable to design the floor slab as part of the girders instead of a separate load upon them, thus obtaining a lower depth-to-span ratio.

For lightness of construction and stability of the structure as a whole, the introduction of continuity into prestressed building frames is desirable whenever possible.

The Leoba method appears to be the best for cast-in-place continuous construction. If precasting is preferred, simple span girders may be made and prestressed satisfactorily by individual bar, cable, or strand method or even by pretensioning. These may then be joined to provide full continuity by short lengths of additional prestressing members over the supporting columns. This additional prestressing may be either in the form of horizontal bars or cables in the top of the girder or of "capping" cables or bars curved over the support and anchored underneath the girder on each side.

For live loads only, continuity also may be introduced by use of standard

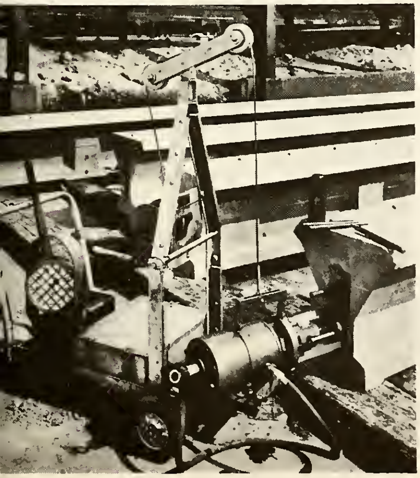


Figure 6 — hydraulic jack and pump in position for prestressing a high-strength-steel bar (left).

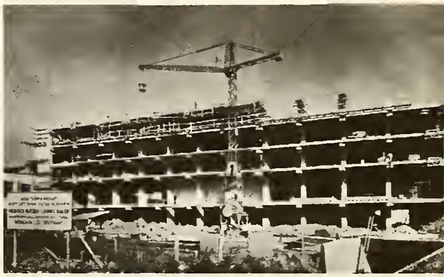


Figure 7 — six-story paper plant, Heidenheim, Germany (above right), *one of the few multistory prestressed-concrete buildings in the world. It was made possible by the use of poured-in-place girders devised for the Leonhardt continuous system of 12-wire cables which minimize friction losses of supports.*

Interior of Heidenheim plant (below right). *Right row of columns rests on rock foundation; left row rests on soft foundation, with hydraulic jacks built into the bases of the columns to compensate for anticipated settlement.*

steel reinforcement in a certain amount of cast-in-place concrete in the upper part of the girder over the supports.

Many variables, such as the type of structure, its location, the amount of prestressing employed, and the method used affect the total bidding price for a cubic yard of prestressed concrete.

A comparison of the bidding prices for quantities of prestressed concrete and reinforced concrete required to perform the identical structural function are shown *(Table 1)*. Totals are inclusive with the concrete made, formed, and placed; the standard steel bent and placed; and the prestressing units made, placed, and tensioned.

Prices for prestressed concrete and reinforced concrete are not always in the proportion shown in the table. Under certain circumstances such as small span, light load, and cast-in-place construction, reinforced concrete will usually be cheaper than prestressed. In other cases, such as some types of large-span bridges, the economies of prestressing will be far more pronounced.

Generally the price of a cubic yard of prestressed concrete should be between $100 and $150; further, it must be remembered that for every two yards of reinforced concrete only about one yard of prestressed concrete is required in an equivalent prestressed concrete structure, and that this cubic yard contains only about one quarter the weight of steel required in the equivalent quantity of reinforced concrete.

When mass-produced precast units are used or large jobs with considerable reuse of forms are involved, the prestressed concrete price may fall below $100 a cubic yard. On small jobs which do not use local contractors or require such expensive extras as the inclusion of design costs and special test beams, the price may rise above $200. Other causes of high prices for prestressed concrete are use of unsuitable prestressing methods and uneconomical design arising from inexperience.

The cost of prestressed concrete consists of the cost of the raw material and the installation cost, which must include the cost of the labor and additional materials required for handling. Thus the fewer the tensioning and anchoring operations and parts required for a given prestressing force, the lower the installation price.

forecast

What is the future of prestressed concrete? It has met each test on a broad front of increasing applications, and it is believed that in another five years every person responsible for the erection of even the most commonplace structure will be familiar enough with this new medium, at least to ask that its suitability for his project be examined. Even so, the rapid evolution of design theories and construction methods emphasizes that prestressing must still be regarded as in its formative period.

While prestressed concrete design is in this stage, to clamp down on it the restrictions of a rigid code of practice would be a severe handicap to its development.

In several European countries, recommended codes of practice for prestressed concrete have been published, and in Germany the seventh revised edition of such a code has appeared within the last year.

The Joint A.S.C.E.-A.C.I. Committee 323 on Prestressed Concrete was formed in 1948 and has since made definite recommendations for prestressed notations and definitions for use in the United States. At the recent Centennial of Engineering, at Chicago last fall, a steering committee was appointed to draft a recommended code of practice for this country. When this code is available it will certainly be of great assistance to architects and engineers, but it should be applied only as a guide and not as a set of restrictive rules imposed on a young and expanding method of construction.

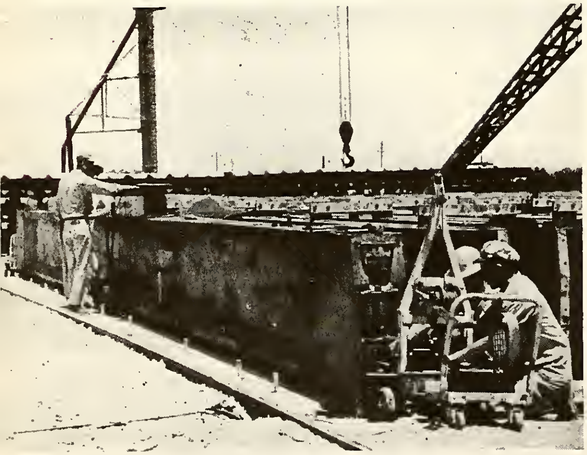


Figure 8—Lower Tampa Bay Bridge, Florida. General view of bare test girder during prestressing operation. Strain gage is set at center of girder.

TABLE I

prestressed concrete		reinforced concrete	
1 cu yd of 5000 psi concrete @ $50	$50	2 cu yd of 3000 psi concrete @ $45	$90
40 lb standard steel reinforcement @ 20¢	8	400 lb standard steel reinforcement @ 15¢	60
80 lb prestressing steel @ 75¢ (120,000 psi working stress)	60		
Total price	$118		$150

THREE BUILDING TYPES

In the next three articles, various principles of structural design for three active building types—apartment houses, shopping centers, and schools—are presented. Illustrations on this folio are elements of buildings that are discussed more fully on the following pages.

Apartment House Construction Methods

Although erected in different areas of the country (two in Georgia and one in Pennsylvania), all of the multistory apartment houses presented on the previous pages were constructed of reinforced concrete for reasons of economy. In each instance, the architects and engineers were of the opinion that for structures of this type, a skillfully executed, reinforced concrete design offered more opportunities for economy than would have been possible through the use of structural steel.

Two of the designs not only utilized the most recent technological advances in reinforced concrete engineering, but also, by exploiting the characteristics of cantilever construction, decreased the amount of reinforcing steel that normally would have been required. This saving was accomplished by capitalizing on continuity and by allowing the combined weight of the cantilever and the exterior wall to reduce the positive bending moment in the slabs nearer the interior of the building.[1] The elimination of dropped beams and girders in all three structures simplified the installation of mechanical services, permitted a freedom of partition arrangement, and provided smooth ceilings for all individual apartment rooms.

Forcefully expressing the character of the structural design, two of the apartment buildings have exposed concrete framing. Properly controlled concrete mixes insure the durability of these surfaces. Although none of the buildings have prefab exterior walls, two firms reported that metal wall spandrels were investigated during the early design stages. At that time, cost prohibited the use of that type of spandrel; further, neither structural nor thermal properties were as advanced then as they are today.

flamingo apartments

Competitive bids received by the architects of this apartment house have demonstrated that a concrete structural system is usually more economical than steel framing for a multistory building. It has been estimated that the nearest comparable concrete framing for this structure would have been at least five percent more expensive and that steel framing with concrete floors would have been about 12 percent more. Of the several concrete designs that might have been selected, the architects and engineers considered the flat-plate method the most economical (there are no applied structural steel shapes in the entire building).

Within the experience of this firm, flat-plate construction has cost about $2.00 per sq ft of supported slab for an entire structure, including the foundations. The Flamingo is said to have been built for about $0.10 per cu ft less than comparable apartment houses erected in nearby areas.

Among the principal economies permitted by the elimination of the beams and girders are the reuse of formwork and the reduction of floor-to-floor heights—requiring less masonry, paint, piping, and work performed by other trades. In deciding whether to use a flat-plate system, it was agreed that the small savings of concrete from ribbed-slab construction would be more than expended by the necessity of a hung ceiling. In the final design, the only suspended ceiling is on the top floor, where it was necessary to accommodate mechanical work and thermal insulation; all other ceilings are painted concrete.

During the preliminary design stages, it was agreed to use exposed concrete as a finish material—both inside and out. It was decided that an exposed exterior frame would not only be more in keeping with the interior exposed surfaces but would also permit savings in finish material that might otherwise be required for an exterior of conventional design.

In plan, the columns are spaced 17 ft apart transversely and 15 ft on center longitudinally; the inner row is staggered about halfway between the exterior columns *(see plan acrosspage for the spacing between columns)*. For this scheme, the transverse spans are thought to be the

Structural drawing of the Flamingo plan (acrosspage) *shows the pattern of both top and bottom reinforcement in a typical bay. Extended top bar at stirrups* (floor section) *acts as negative reinforcement.* Architect, John H. Graham; Associate Architects, Sweet & Schwartz; Structural Engineer, Dr. Jacob Feld. Photo: courtesy Turner Construction Co.

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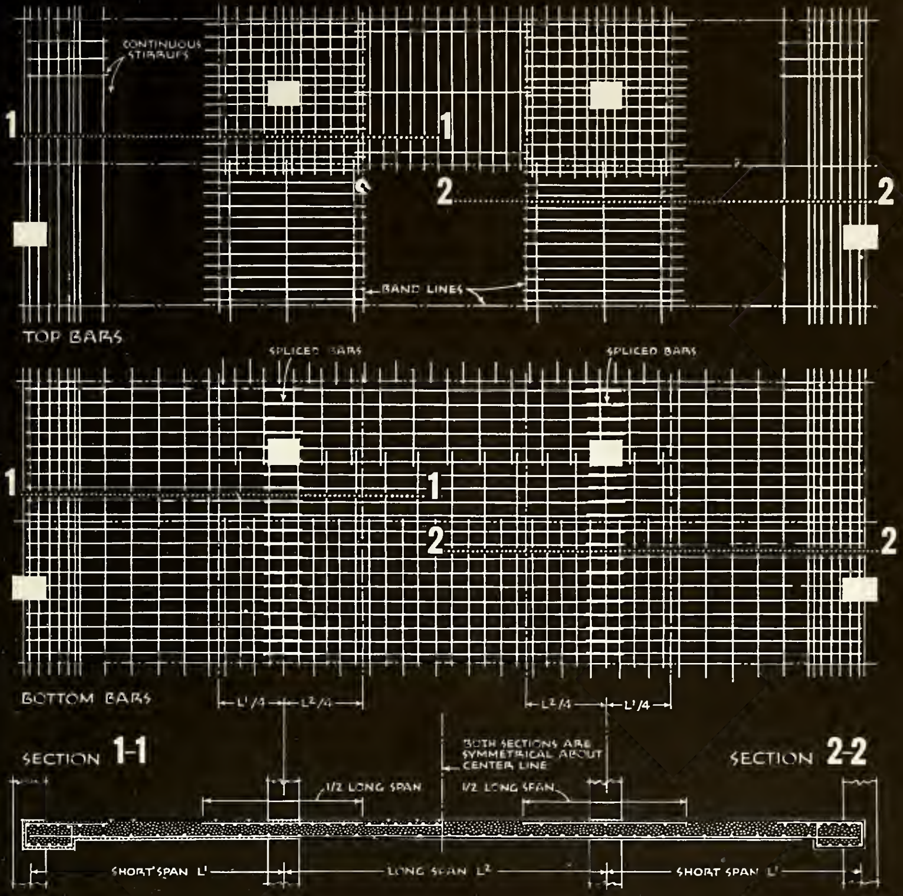
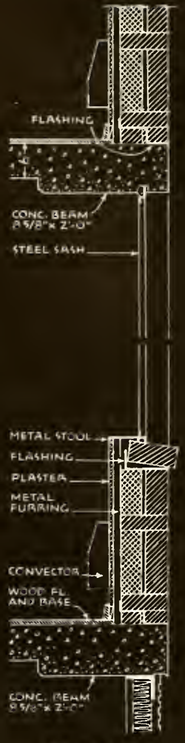
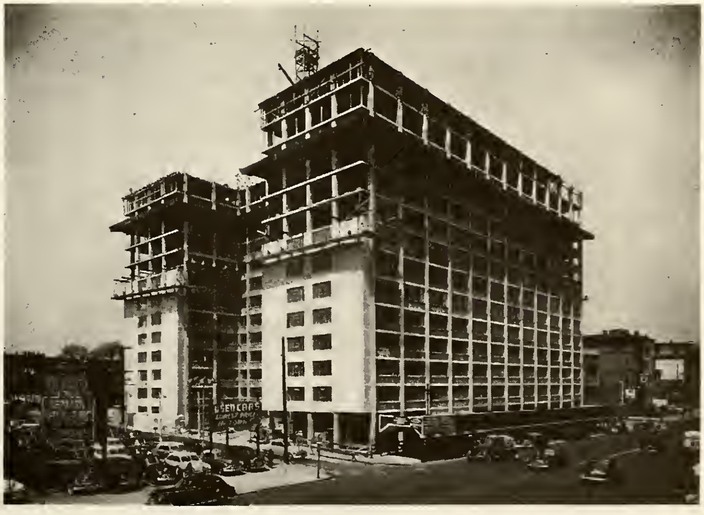
[1] *That this principle can also be used to advantage in structural steel design has been discussed on page 16,* "Cantilevered Steel Construction," *and on page 18,* "Steel Design Economy."

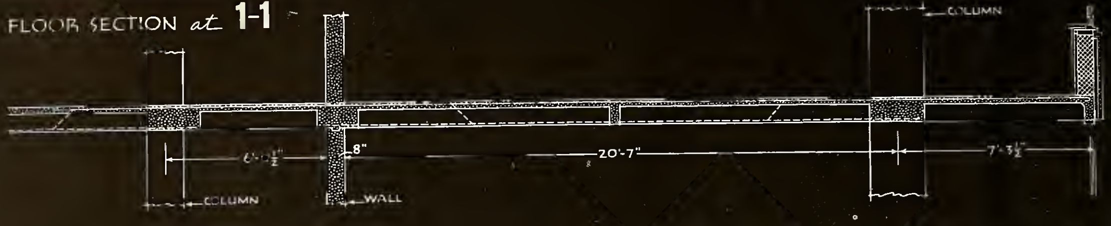




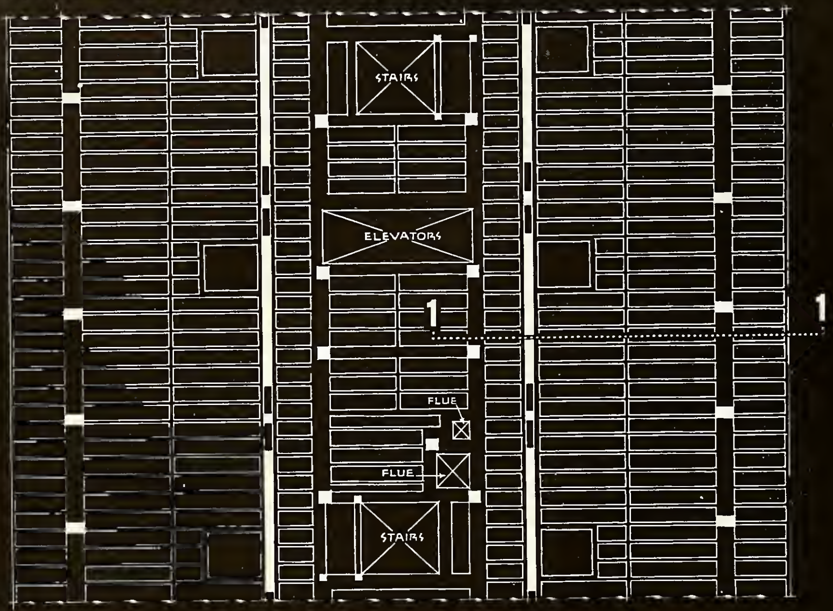
TYPICAL WALL SECTION



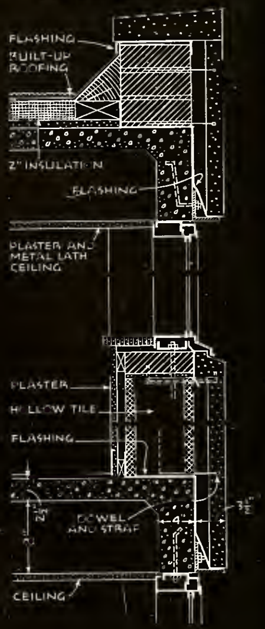
FLOOR SECTION at 1-1

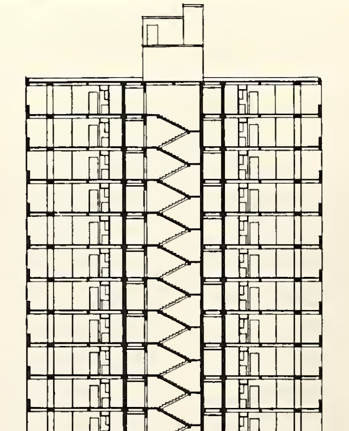


REFLECTED CEILING PLAN



WALL SECTION





maximum economical length. Floors were designed for a live load of 40 psf with an allowance of 20 psf for partition and finish *(see reinforcement pattern of slabs on preceding page)*; 3000 psi concrete was specified and although no admixture was used, careful control of proportioning and placing resulted in extremely durable concrete surfaces.

Footings were placed on a soft mica schist rock and no special problems were encountered except for some minor underpinning of adjacent structures.

drayton arms apartments

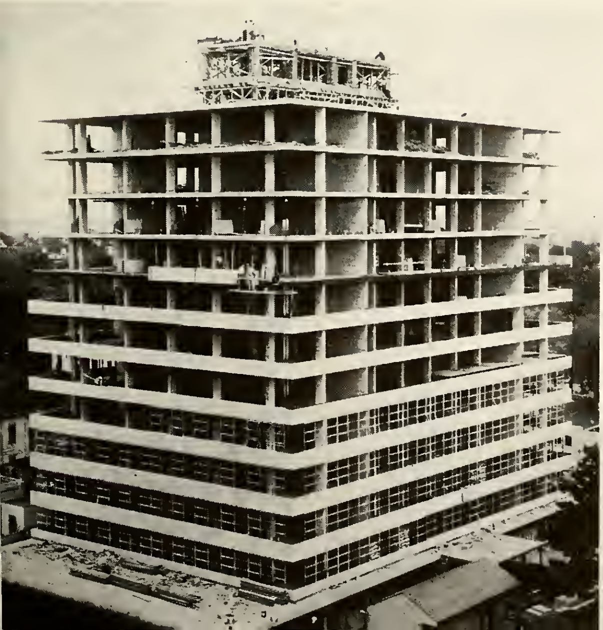
The core of this building, containing elevator and stair towers, halls, storage closets, etc. *(see detail drawings acrosspage of plan and sections)* was designed as a rigid frame to resist all horizontal (wind) loads as well as to support vertical loads. Wind beams and columns were eliminated as the slab and beam construction outside of the core acts as a horizontal cantilever laterally braced and transmits all horizontal loads to the core. All computations for wind were based upon 30 lbs per sq ft of vertical projection. On rechecking, it was determined that by meeting local and national building codes governing minimum wall thicknesses, the present construction can actually resist a load several times greater than 30 psf.

Spans between peripheral columns presented no particular problems, as the design followed conventional pan-band design procedures. The cantilever was definitely helpful in reducing the positive bending moment in the ribbed slabs between columns and core. In addition, the cantilever was so proportioned that the negative moments at each side of the peripheral columns were equal, as well as being equal to the negative moment at the core wall. By such a balance, the moments in the exterior columns were minimized so that the columns could be kept to minimum size. Approximately 30 ft is considered the maximum economical span between columns and core walls for a building of this character and occupancy (many factors, of course, could alter this figure). Given a 30-ft span, a cantilever of about 10 ft 6 in. is required to balance the positive and negative moments described above. (The span between core and exterior columns in the Drayton Arms is actually 20 ft 7 in. and the cantilever extends 7 ft 3½ in.) For the apartment rooms, the design load included 40 psf live load and 15 psf for partitions; corridors were assigned a live load of 80 psf.

Like the designers of the Flamingo apartments, these architects and engineers investigated the possibility of using prefab metal walls; at the time, however, these had not yet been fully developed. In the final solution, lime-faced spandrels were backed with 8 in. x 12 in., hard-burned structural terra cotta tile.

barbizon tower apartments

Undoubtedly, the ground-floor garage was a prime factor in the flexible and economic plan that was developed for this building *(see drawings on the following page)*. A ribbed-slab floor system *(see reflected ceiling plan)* was selected because its extra depth was needed to provide a rigid cantilever, and also because it reduced the amount of reinforcing steel that would otherwise have been required. Wide flat beams reduced the framework and produced a smooth ceiling without breaks to which contact lath could easily be applied. It was felt that these features more than outweighed the additional reinforcing normally needed for flat-beam construction. Both the flat-band, cantilevered-slab structural system and the constant floor-to-floor heights made the repeated use of forms possible. Rubbed-concrete-bearing walls at each end of the structure were designed



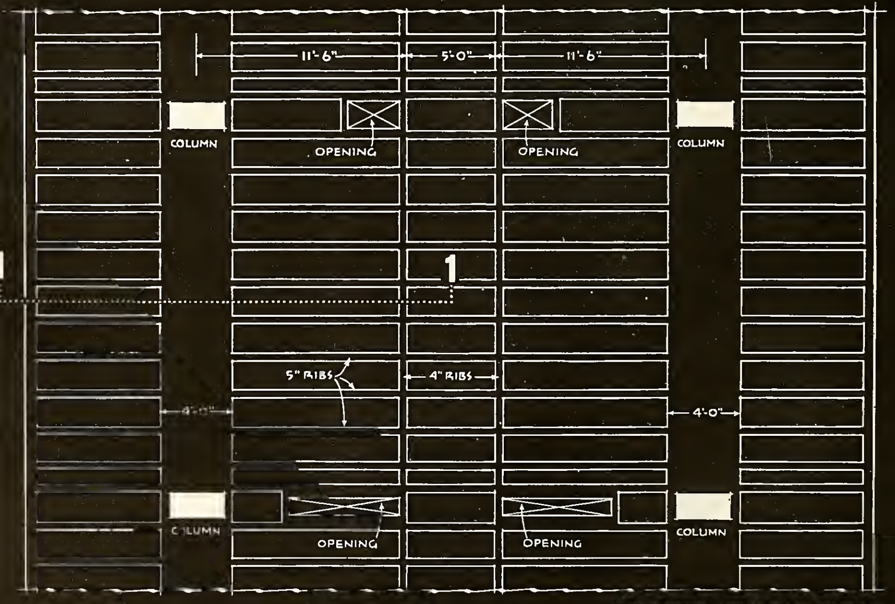
The core of the Drayton Arms, designed as a rigid frame, resists all horizontal loads and supports vertical loads. In the event of an aerial attack, the occupants would be afforded some measure of bomb-blast protection by the core. Architects, Cletus W. Bergen & William P. Bergen; Structural Engineer, William H. Armstrong, William Edwards, Associate. Photo: Andrew Bunn

Ribbed-slab construction in the Barbizon Towers provides the required rigidity for cantilevers extending from the wide flat beams. Only two rows of columns, at ground level, simplifies parking. Architect, John W. Cherry; Associate Architect, William H. Evins; Structural Engineer, Harry G. Hunter.

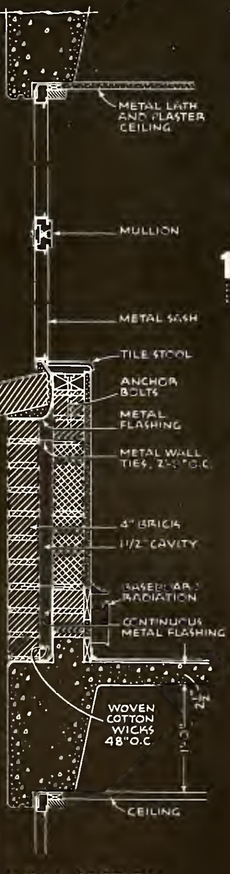
not only for achitectural effect but also for the stability that they lend to the structure.

Two lines of struts were required in the 28-ft span *(see detail drawings below)* for both stiffness and even distribution of the partition loads. These struts were located so that they would frame the service shafts; only minimum reinforcement was placed. To limit deflection, spans in excess of 22 ft (in a longitudinal direction) would not have been advisable unless the depth of the beams and joists was increased. As in the Drayton Arms, a balanced rectangular section determined the most economical length for the cantilevers. In general, a 40 psf live load was used and the total load used for the joist system was 140 psf. An admixture in the 3000 psi concrete provided a smooth flow—leaving the concrete free of voids when the forms were stripped.

Spread footings resting on clay were suitable for the support. As any wall insulation in this area of the country is comparatively rare, uninsulated cavity walls were considered adequate.

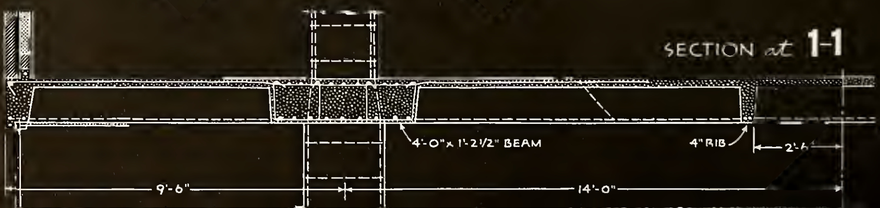


REFLECTED CEILING PLAN


METAL LATH AND PLASTER CEILING
MULLION
METAL SASH
TILE STOOL
ANCHOR BOLTS
METAL FLASHING
METAL WALL TIES, 2'-0" O.C.
4" BRICK
1 1/2" CAVITY
BASEBOARD RADIATION
CONTINUOUS METAL FLASHING
WOVEN COTTON WICKS 48" O.C.
CEILING

WALL SECTION

SECTION *at* 1-1



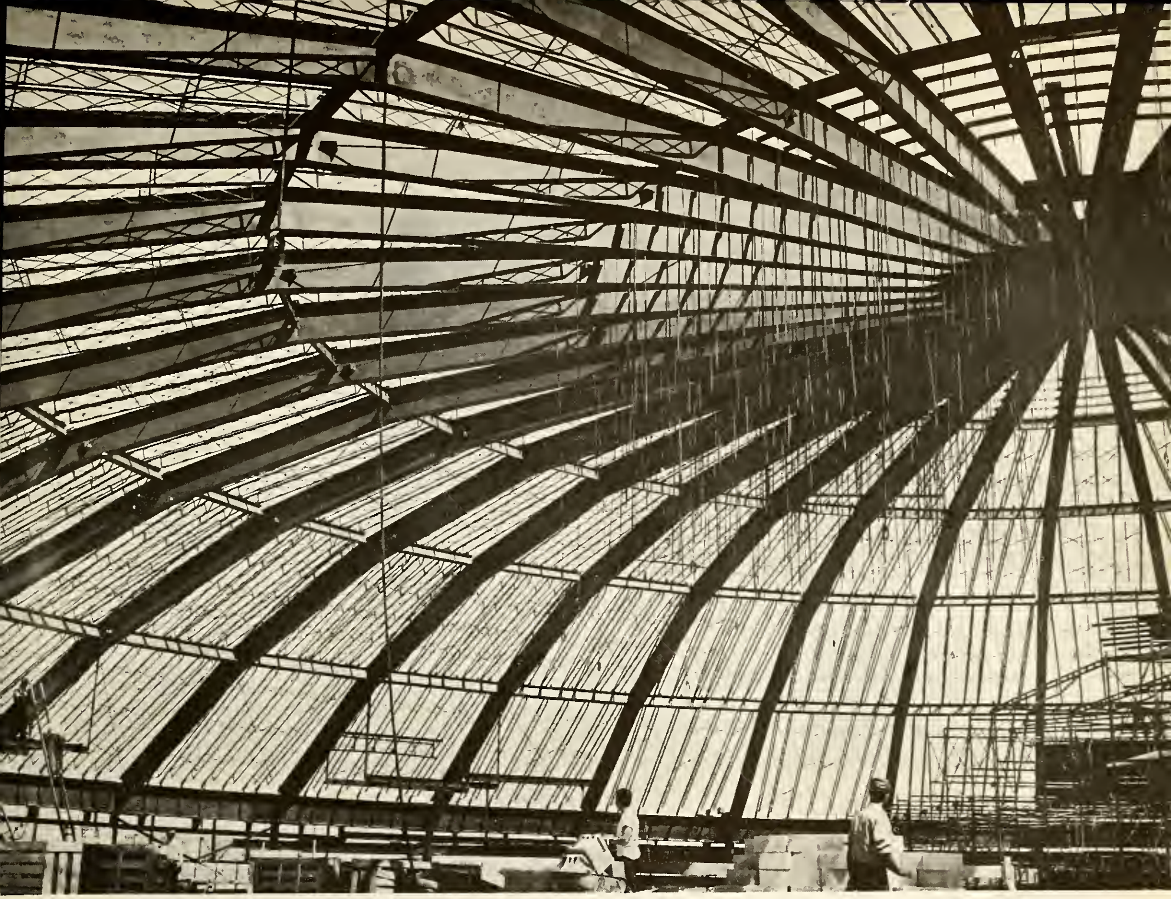


Figure 1—domed roof 222′ in diameter for Jordan Marsh Store, Shoppers' World, Framingham, Massachusetts; Ketchum, Gina & Sharp, architects; Severud-Elstad-Krueger, engineers. Impressive. column-free area.

The Shopping-Center Structure

BY VICTOR GRUEN

The selection of the structural framing for a shopping center project is affected by many factors. Some of these are constant; most, however, vary greatly in relative importance from project to project. A thorough, general study of the problem will not produce a recommendation for *one* preferable system, but will help to establish certain basic relationships characteristic of any one project. Such a study will also indicate which of the most recent developments in structural design promises most for development and application to shopping-center framing.

We shall list the most important factors affecting structural framing and briefly examine their influence on the selection and development of framing schemes.

size of project

A small shopping center, especially if located far from a large city, will probably be best framed by the conventional methods prevalent in the region where the center is located. Imagination in applying such common systems as trussed rafters, open-web steel joists, or beam-and-slab concrete framing can bring entirely satisfactory results. On the other hand, a regional shopping center, located where competitive, aggressive, and experienced contracting firms are available—covering several hundred thousand square feet of floor area, and designed so that a repetition of typical elements will occur on a large scale—offers an excellent chance for an investigation of the most ad-

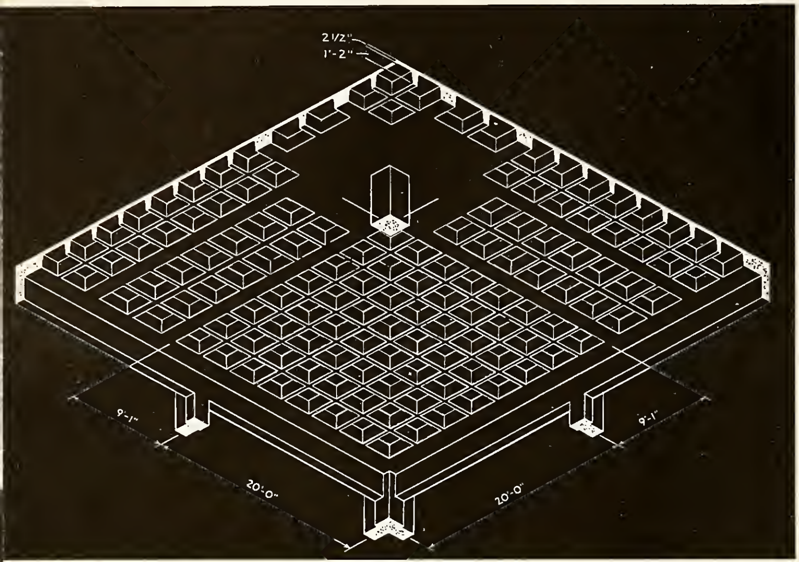


Figure 2—"waffle-type" flat slab designed by Edgardo Contini of Victor Gruen Associated Architects & Engineers, for Northland Center.

vanced design techniques and for original developments conceived to most satisfactorily answer the requirements of the largest number of effecting factors. In such a case, the investment in design and construction experimentation will be well justified by the possible economies and advantages achieved.

location of project

Location will effect structural design in several ways. Differences in building codes (particularly the reluctance of some building departments to accept new techniques of analysis or tests, or of departing from obsolete and arbitrary restrictive rules) may penalize the use of certain materials. Climatic differences evidently bring complex and controversial influences. The supply of some materials is also effected by geographic location. The economical availability of good quality lightweight aggregate for reinforced concrete is, for one example, geographically limited for the present by the high cost of transportation for a material of such bulk. Further, established habits of local contractors have to be accounted for. There are still several areas where precasting techniques are frowned upon as something very daring and experimental.

physical characteristics of site

These characteristics are likely to govern the selection of the foundation system. Where unusual soil conditions are encountered, site characteristics represent an important secondary factor effecting the selection of the framing for the superstructure.

The foregoing factors, of course, are not peculiar to shopping centers; however, they combine with the more specific ones (which follow) in effecting the final selection.

selection of column spacing

There are three primary types of buildings generally present in a large shopping center:

(1) The typical row-type building. These are one or two stories high, 100′ to 150′ in depth, and will accommodate tenant stores of different widths.

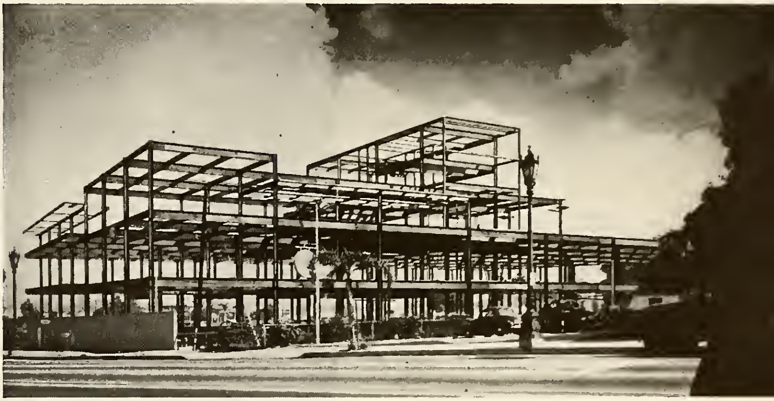
(2) The special-purpose-type building. Accommodating major department stores, these may be multistory and, in general, have a compact plan shape.

(3) The supermarket-type building—usually one story high.

All of these, from a merchandising standpoint, will benefit from complete elimination or, at least, reduction to a minimum of interior bearing supports. On the other hand, long unobstructed spans, if feasible from an engineering standpoint, unavoidably conflict (especially for floor framing) with the primary underlying factor of cost of construction. Cost has not previously been mentioned simply because, within the economic framework representing the essence of a shopping center, it effects all others.

At present, very large clear spans are economically feasible for roof framing only. Large spans, up to 200′ or 300′, can be achieved by means of trusses, arches, rigid frames, and, more dramatically, by means of domed structures of thin concrete shells or structural steel framing (*Figure 1*). On the other hand, it is very likely that changing concepts in department store planning, enabling great framing depths without loss

Figure 3—*continuous field-welded steel frame for Robinson's new Beverly Hills store in California (right); Pereira & Luckman, architects.*



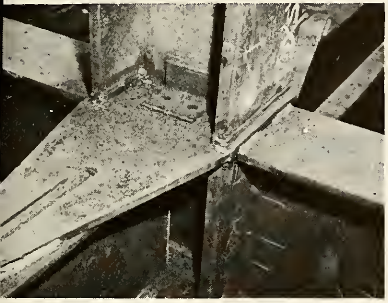


Figure 4—detail (left) of welded connection for columns and girders in field-welded steel frame of Robinson's Beverly Hills store.

of useful space, or new structural developments such as the practical application of prestressing techniques for concrete, will allow an increase of economically feasible column spacing beyond the present standards. It is unquestionable that the major challenge facing engineers concerned with shopping-center framing is the development of economical as well as structurally sound larger spans. In general, it will be found that merchandising layout for department-store-type buildings suggests an even spacing in both directions. Flat-slab concrete construction (for which extremely interesting optical methods of stress determination have recently been developed) lends itself for column spacing up to 25′ or 30′. For larger spacings (or, under present restrictions, for maximum economy of reinforcing steel) concrete-waffle-type flat slabs are very satisfactory (*Figure 2*). Were it not for the present restrictions, however. structural steel would still provide a very competitive type of framing—especially with an increased use of field welding to create continuity of both vertical and horizontal members. The recently completed Robinson's Store in Beverly Hills achieves a remarkably light steel framing on a 32′ x 32′ typical column spacing (*Figure 3*). In fact, it is likely that advanced structural steel design, exploiting continuity in a multi-directional way rather than as the obvious linear extension of the traditional two-way simple-span riveted framing, will soon find successful application and allow lighter framing for longer spans (*Figure 4*).

For the typical, row-type buildings that are sub-divided into leasable units of narrow frontage and considerable depth, it will be found preferable to minimize the number of interior supports by maintaining a longer column spacing in a transverse direction and a narrower spacing in a longitudinal direction. This solution suggests a two-way framing which, if less economical than flat-slab construction, offers another advantage—that of framing flexibility.

For the supermarket-type building, if present in the project as a separate unit, it is desirable to span the roof as a clear span, if for nothing more than to meet the demand of the supermarket operator who often objects to having his counter layout dictated by column spacing. Wood trusses, lamella framing, or glued laminated-wood arches offer reasonably inexpensive solutions for clear-span roofs.

framing flexiblity

Of all the factors effecting the selection of a structural framing method, its adaptability to alterations is perhaps the most specific consideration. Maximum flexibility is required for the typical row-type building for the following reasons: (1) not all of the space may have been leased by the time the center is under construction or completed; (2) changes of tenancy will undoubtedly occur, in time. It is often desirable to provide for future vertical expansion, rather than by the addition of new wings or buildings. In this manner, the delicately balanced plan pattern of the shopping center need not be disturbed. Thus, it becomes important that the floor framing and the roof framing, if designed for possible floor use, allow for the future openings of shafts for stairs, escalators, ducts, elevators, etc., without creating ma-

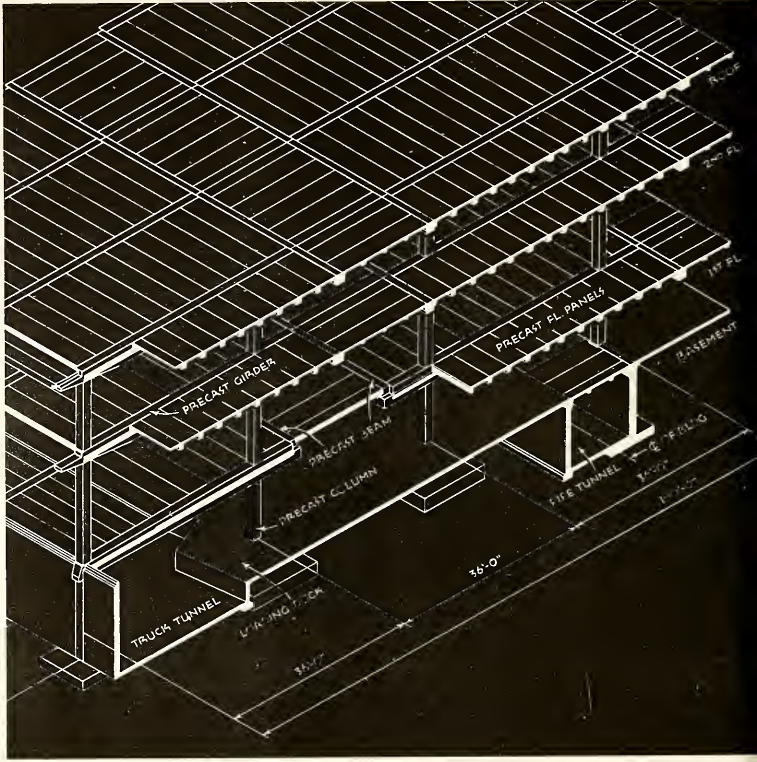


Figure 5—all-precast framing system for the J. L. Hudson Company's tenant buildings at Eastland Center, Detroit, Michigan; Victor Gruen Associated Architects & Engineers.

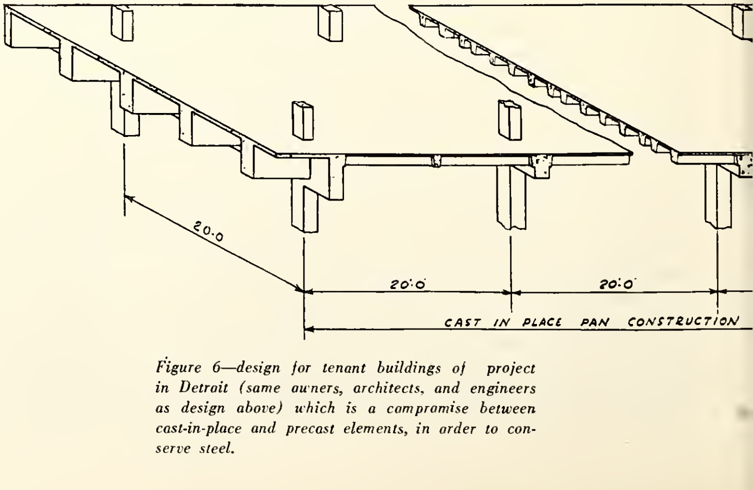


Figure 6—design for tenant buildings of project in Detroit (same owners, architects, and engineers as design above) which is a compromise between cast-in-place and precast elements, in order to conserve steel.

jor structural difficulties. Changes of this nature will not occur frequently enough, however, to warrant an excessive investment to achieve absolute flexibility. An optimum compromise is to be sought; too little is known about the operational demands of shopping centers at present to state what degree of framing flexibility approaches this optimum.

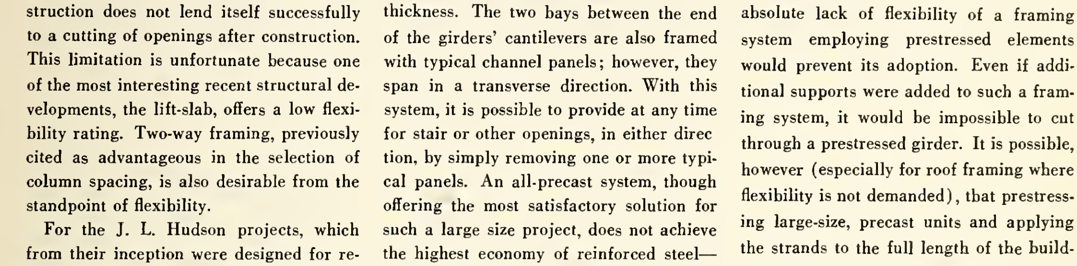
In general, the demands of flexibility factors are not too taxing on structural steel framing which, by its very nature, is eminently suitable for alterations.

But reinforced concrete does impose limitations on flexibility. Flat-slab construction does not lend itself successfully to a cutting of openings after construction. This limitation is unfortunate because one of the most interesting recent structural developments, the lift-slab, offers a low flexibility rating. Two-way framing, previously cited as advantageous in the selection of column spacing, is also desirable from the standpoint of flexibility.

For the J. L. Hudson projects, which from their inception were designed for reinforced concrete framing, due to material restrictions, an exhaustive study was conducted on the possibilities of precast construction. This technique seemed to present possible economies as well as excellent qualities of flexibility. In the first project (Eastland), the framing for the typical row-type building has been detailed for all-precast construction—entirely eliminating scaffolding and formwork. The framing consists of 18″ x 18″ precast columns, spaced 36′ on center, which support 18″ wide double-cantilever girders spaced 20′ on center (*Figure 5*). A specially designed connection detail allows for ease of erection and at the same time re-establishes a high degree of rigidity between girders and column. Spanning the girders are typical precast 4′ wide channel panels of 2½″ slab thickness. The two bays between the end of the girders' cantilevers are also framed with typical channel panels; however, they span in a transverse direction. With this system, it is possible to provide at any time for stair or other openings, in either direction, by simply removing one or more typical panels. An all-precast system, though offering the most satisfactory solution for such a large size project, does not achieve the highest economy of reinforced steel—the price is paid for flexibility at the expense of continuity!

For the project presently being detailed (Northland), a compromise solution was adopted in an effort to achieve the maximum saving in steel tonnage. The framing will consist of cast-in-place, continuous, deep-ribbed pan construction throughout, except on the two interior, center bays where most of the foreseeable future openings may be located. These are framed by means of precast concrete joists, supporting a 2½″ cast-in-place slab (*Figure 6*).

During the preliminary studies, the feasibility of using prestressed elements was investigated. It was found, however, that the high ratio of live to dead load for floor construction penalized the design of continuous elements. It was also felt that the absolute lack of flexibility of a framing system employing prestressed elements would prevent its adoption. Even if additional supports were added to such a framing system, it would be impossible to cut through a prestressed girder. It is possible, however (especially for roof framing where flexibility is not demanded), that prestressing large-size, precast units and applying the strands to the full length of the building, to minimize the cost of anchoring devices and stressing operations, may lend itself to very significant developments in the search for economical long-span framing.



fire rating factors

For department store buildings where large, undivided floor areas are demanded, Class I construction will be required for all but the smallest projects. Either reinforced concrete or fireproofed structural steel can be used. Developments in lightweight fireproofing and in lightweight aggregates for concrete topping are in favor of structural steel framing. On the other hand, the need for flexibility on store ceilings—where lighting fixtures, air-conditioning outlets, and other inserts may need relocations and additions—makes it almost mandatory to divorce the fireproofing ceiling from the finished ceiling. It may, therefore, often be more economical to adopt a basic reinforced concrete structure with finished ceiling suspended directly.

For the typical row buildings, where the total floor area can be divided into smaller units by using firewalls or separations between tenants, the selection of framing systems becomes more complex. This is because differences in fire ratings and consequent insurance costs have to be projected against differences in initial construction costs. Furthermore, the introduction of sprinklers—a reasonable enough investment—will considerably reduce the insurance cost of systems with otherwise high rates. Thus it becomes impossible to give any rule of thumb. In ease case an exhaustive comparative analysis will have to be made to determine the most economical solution. It is possible that, under certain circumstances, wood framing—in the form of arches, trusses, glued-plywood-box girders for roofs used in combination with structural steel or concrete girders for floors—may well prove to offer an entirely satisfactory solution.

owner's or tenant's specific requirements

These, of course, are highly unpredictable. It has been mentioned that some supermarket tenants will not consider anything but a clear-span roof. The clear-span domed roof over the main department store at the Framingham center has also been cited. It is unquestionably a desirable luxury to have an uncluttered area of such size within which to develop the merchandising layout. Yet, other major stores have been successfully planned on the basis of conventional open-column spacing. The conclusion: that the asset of clear span is evaluated with different factors by different tenants.

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After having thus surveyed the influence of general factors on the selection of a structural system, a brief mention can be made of some specific framing problems that are characteristic of shopping center projects. It is accepted as almost mandatory that a covered pedestrian sidewalk be provided at the periphery of the store buildings. It is also very desirable to eliminate all columns from the storefront line of typical row-type buildings in order to allow for maximum flexibility in the subdivision of tenants' space and in the design of storefronts. This problem can be solved either by recessing the columns a reasonable distance inside of the store space and cantilevering the horizontal framing, or by providing colonnade columns at the outer edge of the sidewalk. Aside from architectural considerations that may influence the choice, it can be noted that the first solution, involving cantilevers of considerable span, is more appropriate where the typical interior transverse column spacing is also very wide. The second solution, on the other hand, lends itself satisfactorily to any selected column spacing.

If the shopping-center plan is developed around a covered mall, there arises the problem of how to roof (elegantly) the public promenade. The use of long-span, precast elements — possibly prestressed — having integral—glass inserts, so that natural light will not be excluded, may lead to interesting solutions.

If truck tunnels for underground service delivery are a part of the project, special framing problems will unavoidably occur. It should be noted that often a large portion of the structure's total cost is represented by special conditions of this sort. As a thorough analysis of the typical framing system is necessary to the selection of the most satisfactory and economical structure, so ingenuity and sustained effort, applied to the design and detailing of secondary elements, is needed to avoid the danger that some features of the project, otherwise very desirable, may become excessive economic burdens.

conclusions

In view of the fact that so many of the concepts are still at a fluid and formative stage, the creative collaboration of architect and engineer is vital in the basic design of shopping centers. Inventiveness and daring are as much bound by considerations of economic necessity as spurred by the magnitude and the extraordinary potentials of the problem. The shopping center offers again, to modern man, the values of informal order, well-scaled environment, and relaxed activity that were characteristic of the old-time plaza or the country market—lost in the fragmentary, unplanned, gaudy development of our time's downtowns.

These same values are in the process of being reinterpreted for modern man in terms of today's economy, up-to-date technology, and contemporary living patterns. Moving as we are in this direction, we have just traveled the first steps. Tomorrow's "plaza" may well be envisioned as one great, cheerful, informal, air-conditioned space, sheltered by a light, luminous, single-span roof. Within this one space—well organized and interrelated — merchandise will be displayed and "shopping" will become again a most enjoyable exciting, and civilized experience! To make such a vision into a physical and economic reality, the combined, interplaying imagination and ingenuity of architects and engineers face a challenging task.

Economy in School Building Design

BY I. E. MORRIS*

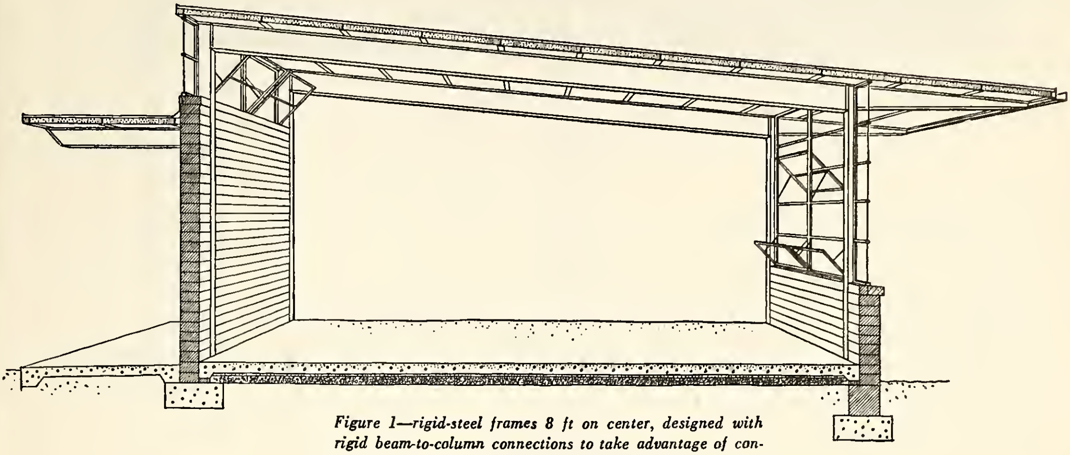

Figure 1—rigid-steel frames 8 ft on center, designed with rigid beam-to-column connections to take advantage of continuity, are suitable for most types of roof decking.

With many sections of the United States launching huge school-building programs, architects and engineers are in an excellent position to do their communities a real service by striving for economy in design.

Maximum economy is attained only by careful attention to detail; this attention must involve an intimate knowledge of structural design as well as a thorough knowledge of material and labor costs. For example, in the design of a one-way solid-concrete slab, there are several reinforcing-bar sizes and spacings which will provide the steel area required for bending moment; however, there is usually one combination which, in addition to meeting design requirements, involves the least amount of labor in the field.

In order to space the bars properly, a workman must mark the intervals on the slab form. Obviously, he can make 500 marks in less time than he can make 1000; further, it requires less time to hoist 500 large bars than to hoist 1000 small ones. These considerations also apply to workmen carrying the bars from the hoist and placing them in the forms. Consequently, a designer requiring 0.33 sq in. of steel per ft in a slab can almost double the labor of placing the bars by requiring ⅜ in. rounds at 4 in. instead of ½ in. rounds at 7 in.

Another consideration is the cost of the bars themselves. The base price of steel per ton is only the beginning—there are size extras, bending extras, quantity extras, etc. The size extra on a ¼ in. round bar is $1.90 per hundred while on a ⅝ in. round bar it is only 25¢ per hundred; therefore, 100 pounds of ¼ in. round bars cost $1.65 more than the same weight of ⅝ in. rounds. In order to reduce the cost of bending reinforcing-steel, the obvious procedure is to require a minimum amount of it to be bent.

In the case of structural steel frames, there is no economy in using innumerable small members in place of a few larger ones —even if the latter involve slightly more tonnage. As the structural steel manufacturers also have an imposing list of extras, the job with the least tonnage is not always the most inexpensive.

Maximum economy, perhaps, is realized from uniformity (or symmetry) of frame layout, whether it be of steel or concrete, as the saving is largely one of man-hours. In the steel-fabricating shop, less time is required to fabricate 100 identical beams than to fabricate 100 beams involving a dozen slight variations. The same considerations, of course, apply to work in the carpentry shop.

Today, concrete is one of the cheapest materials used in construction; therefore, in the monolithic concrete building, particularly in schools with several identical wings, there is an inherent economy which few people understand, and even these few are reluctant to believe what they see. The basic explanation is that we have relatively cheap concrete placed by unskilled labor, as compared with more expensive masonry placed by skilled labor. When the former two factors are combined with many re-uses of formwork, they produce a truly economical structure.

For one-story schools composed of multiple wings, there are several framing schemes which are economical:

1. Rigid-steel frames on 8 ft modules produce, or can produce, a repetition of detail which escapes most of the annoying extras mentioned; further, the 8 ft spacing is suitable for most of the various types of roof deck *(Figure 1)*. Also, the top members of the frame may pass over the columns to support a canopy if desired. The principal consideration is a rigid beam-to-column connection in order to take advantage of continuity.

2. The corrugated slab, which was introduced in this country by the writer early in 1951, makes an ideal roof for the one-story school *(Figure 2)*. It is adaptable to almost any classroom arrangement and, because of the pleasing ceiling effects which may result, it is particularly effective over auditoriums and cafeterias where longer spans are involved. Such construction requires about 20 percent less steel and concrete than conventional types of framing.

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* *Consulting Engineer, Atlanta, Ga.*

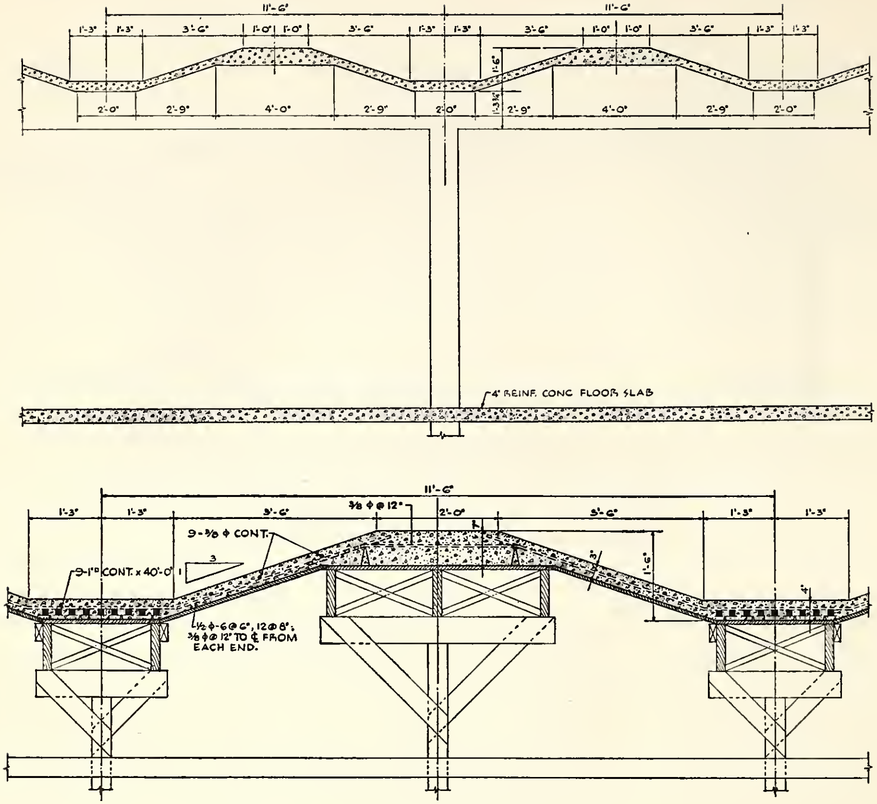


Figure 2—corrugated-slab construction (top) *is ideal for the one-story school and is particularly effective where longer spans are required. Suggested formwork is shown* (bottom).

3. The well-known wall-bearing construction with open-web steel joists is also a solution. But, as the present tendency is to place windows continuously along at least one wall of school buildings, a wall-bearing job without walls becomes somewhat complicated.

Another important feature for a building with a large perimeter, say 2000 ft, involves architectural as well as structural cost. Suppose one structural frame permitted window heads to extend to the underside of the roof deck while another frame, slightly less expensive, required a foot of masonry above the window heads. If we were to consider only the comparative cost of the two frames, we should be misled. The building with the less expensive frame would require an additional 2000 sq ft of wall, which would change the picture entirely. In either case, should a parapet 2'-6" high be included in the design, an additional 5000 sq ft of wall would result. It follows that maximum economy can be attained only by elimination of all nonessential features. In some cases, however, a parapet is no doubt essential.

Column spacing is a problem which cannot be solved satisfactorily by a general rule. In the case of a steel frame, suppose a series of beams supported by columns spaced 20 ft on center, cover a distance of 100 ft (normally, this is not a bad spacing). Then suppose the spacing is reduced to 16'-8", which would require an extra column. If the beam tonnage saved by the shorter spans was materially more than the weight of the added column, the shorter spans would, of course, be more economical. The saving in beam weight is not the only consideration, however, as the additional column requires another connection, another pair of anchor bolts, another base plate and, if the columns are concealed, more furring involving skilled labor. The excavation and the concrete for the additional footing would not add an appreciable amount because the area of footings under

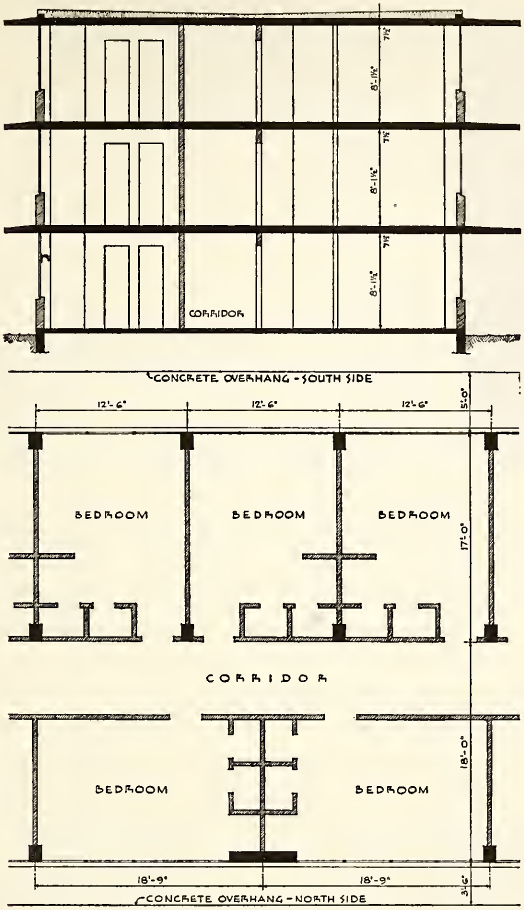


Figure 3—flat-plate slabs permit reduced story heights and require only simple formwork (left). *Flexibility of column spacing is an additional advantage of this construction technique* (below).

columns at the greater spacing would be larger than those for the shorter column spacing. So a saving at one point sometimes increases costs at other points. The designer should also recall that there is seldom economy in making a beam deeper and lighter, if the increased depth requires a greater story height.

There is one school of thought which persistently extols the virtues of bearing walls and open-web steel joists. Although it is admitted that this type of construction is, no doubt, the easiest to design and to build, its economy is open to argument. An exterior building wall has two primary functions: one is to protect the interior of the building from the elements; the other is to produce a reasonably pleasing appearance. If a wall of minimum permissible thickness, after performing these two functions, will also support floor or roof loads, it is economical. If the thickness must be increased, or if the wall must be strengthened in some other way merely as a substitute for a few light beams and columns, then its economy begins to disappear. When open-web joists are used for a floor system, the total floor thickness on a 15 ft span can hardly be less than 10 in.; a concrete slab, however, would normally be 5 in. thick. Since window heads would not be above the bottom chords of the open-web joists but could extend to the underside of a concrete slab, the latter would save about two courses of brickwork in each story. Therefore, in figuring relative costs, it is incorrect to compare only the square-foot cost of the floor system. The writer has known this to be done when one system required a depth of nearly 3 ft from ceiling to the finished floor above, while the other system required less than 18 in. Obviously, such comparisons are very misleading.

The all-concrete frame building can be divided into three major types: the beam-and-solid slab, the flat-plate slab, and the ribbed slab (either with dropped beams or with wide flat beams having a depth equal to the depth of the joists). The wide flat-beam type is, as a rule, most economical, as well as being most satisfactory from many other viewpoints.

The beam-and-solid slab type is particularly suited to schools requiring spans of 15 ft to 22 ft, the goal being to hold the slab thickness to 6 in. or less. Solid slabs create a a considerable dead load on the beams when the thickness exceeds 6 in. With beams placed along corridors, there are no unsightly projections into the rooms and, with attention given to forming, a smooth ceiling requiring no plaster is easily obtainable. A column spacing of 14 ft to 20 ft in the direction of the beam span is good practice, requiring a beam depth of 14 in. to 20 in. which produces a reasonable balance between concrete and steel.

Flat-plate slabs *(Figure 3)* have become quite popular in recent years, and their economy may seem incredible to one accustomed only to thin slabs and deep beams. The economy of the flat plate lies in the simplification of formwork and in the reduction of story height below that required for dropped beams. These two items, simplification of formwork and re-

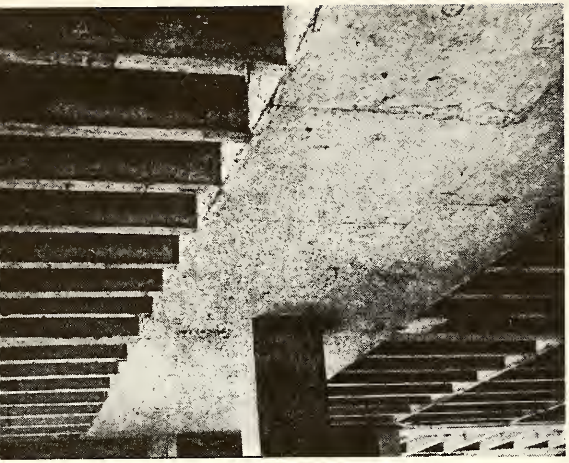
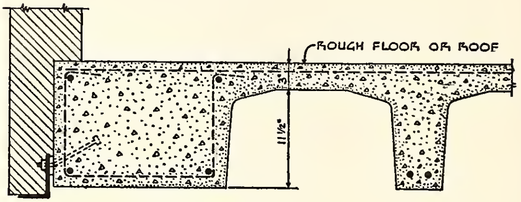


Figure 4—ribbed slabs with wide flat beams of equal depth produce a smooth ceiling without projections to interfere with mechanical equipment (left). *This type of construction utilizes flat spandrel beams of the same form as the interior beams* (below).



duction of story height, play a most important part in cost reduction. If a concrete slab 7 in. to 8 in. thick can replace a floor system 2 ft thick, it permits a possible reduction of 1'-4" in each story height. And the saving applies not only to masonry but also to columns and vertical runs of pipes and ducts, plus many other items less tangible.

The best column spacing for the flat-plate floor is from 12 ft to 20 ft, although a high degree of economy has been attained with column spacings up to 30 ft and slab thicknesses up to 12 in. It is difficult to believe that such slabs could be economical, but bids turned in by many contractors tell the story. Often, the alternative to these slabs is a floor construction involving huge beams, with doubled form-cost and much greater story heights.

The ribbed slab with wide flat beams has also been used extensively *(Figure 4)*. Its economy has been proved again and again. Normally, the ribs are made deeper than is required by moment and shear, but the additional concrete is negligible since it is added only to the narrow ribs or joists. The extra depth reduces the steel for the joists and gives additional depth to the wide flat beams, which are the same depth as the joists. The result is a smooth ceiling with no projections to interfere with mechanical equipment. Moreover, where it is necessary for vertical runs of pipe to pass through beams, the metal forms at these points may be held back in order to widen the beam sufficiently to compensate for the loss of area resulting from passage of pipes. With no projections below the ceiling line, the forming consists solely of slab forms which are cheaper than beam forms.

As for spans, ribs 5 in. wide and 12 in. deep, spaced 25 in. on center, with 2½ in. topping, develop a total depth of 14½ in. and will economically span 24 ft or more. By retaining the 2½ in. topping and increasing the rib depth, which in turn increases the beam depth, it is feasible to span 40 ft.

The column spacing in the direction of the beam spans should not exceed 16 ft for maximum economy, although much greater spans have been employed successfully. Since the depth of the beams remains the same as the depth of the ribbed slab, the greater cross-sectional area required for bars and for shear is obtained by widening the beam.

The foundation of a wall-bearing structure having considerable perimeter is another instance where economies may be realized. Frequently, because of soil conditions, the wall footing may be 5 ft or more below existing grade. Current practice is to excavate by hand for a footing 14 in. to 24 in. wide. After the wall is built up from the footing, the trench is backfilled.

But with a trenching machine, it is cheaper to excavate a trench 12 in. wide and fill the excavation with concrete having a 28-day strength of about 1500 psi. In this way that portion of the wall below existing grade is filled by a material cheaper than masonry, and the material is placed by unskilled labor instead of skilled labor. No backfilling is required. The 1500 psi concrete is stronger than most masonry; and, since the masonry wall is not reinforced, there is no point in reinforcing the concrete wall.

When concrete is thus poured against earth, the friction between earth and concrete tends to spread the load on the soil at the bottom of the wall. With a wall 3 ft high, for instance, the bearing area on the soil at the level of the bottom of the wall may be considered as about 3 ft to 5 ft per foot of wall. As the wall height increases, the equivalent footing width becomes greater.

In several recent instances, the writer has obtained comparative costs from contractors. For only materials in place, the average figures were 60¢ psf for the concrete wall poured into the excavation, and 75¢ psf for 12 in. masonry walls built up from footing to underside of first floor. In these instances, however, the walls were built of 12 in. concrete block. The figures are even more favorable when we consider that the poured-in-place wall requires less excavation, and cheaper excavation with no backfilling.

A careful study of each individual building is required to attain maximum economy; this study should begin with the first architectural sketches.

INSULATION AND STRUCTURE

When discussing a building, one often finds himself reporting on its structure and insulation simultaneously. This is specially true of those buildings in which the control of sound is an essential element of design. Two such structures are the Orange Coast College Technology Building, Costa Mesa, California (Robert E. Alexander, architect) and the Montana State University School of Music, Missoula (Fox & Ballas, architects). At the Technology Building, the primary acoustical problem was to keep the noise originating in the shop areas from interfering with the lectures in the nearby classrooms. The noise levels to be isolated were quite high and the main locations of noise entering a classroom were: (1) along the southwest wall (from adjacent courtyard activities and noises transmitted through the northeast shop walls); (2) through the roof (from noise transmitted through shop roof windows as well as noise from courtyard activities); (3) the northeast window wall (from noise diffracted around the roof and also from foot traffic and conversation noise on that side of the building). To obtain the desired acoustics for the classrooms, the architect had to eliminate all openable windows on the northeast wall, provide a more sound absorbent roof than would otherwise be used, and use acoustically good doors, tightly closed. Also, by designing the classroom with an auxiliary ceiling and by adding lined ducts or baffles to all openings needed for ventilation, he obtained a structure having approximately uniform sound transmissivity. At the School of Music the problem was quite similar except that the noise to be kept out of the classrooms originated in the practice studios, recital hall, instrument lab, and choral lab. Along the west classroom wall (farthest from the noise sources), light-directing glass block, vision strips of insulating glass units, and vertical limestone louvers properly oriented insure both quality natural lighting and minimum sound transmission. As the sound transmission of a wall is directly related to its mass, 8 in. concrete walls were considered necessary for the corridors. Steel angles, bolted to these walls, support isolated concrete corridor floor slabs. In the classrooms wood floors were laid over sleepers mounted on metal and felt acoustical chairs.

That the problem of insulation from radiologic effect is also a function of structure is discussed by Carl Braestrup (*pages 92 to 99*).

Structural X-Ray Protection

BY CARL B. BRAESTRUP*

introduction

Handbook 41, National Bureau of Standards, contains the latest X-ray protection code.[1] With this publication, the hospital architect has available authoritative and detailed recommendations for structural shielding against radiation. The Handbook does not attempt to explain, however, the fundamental principles upon which the recommendations are based; nor does the code illustrate their application with typical examples of protection design. Consequently, the architect without special training in radiologic physics may have difficulty in applying the data of the Handbook to his particular problems of X-ray shielding. It is the purpose of this article to provide this supplementary information.

radiation hazards

Damage caused by overexposure to X-rays includes permanent local and systemic injuries. Typical local effects are the production of skin ulcers, which may become malignant, and the temporary or permanent loss of hair. These results are usually caused by improper operating techniques rather than by inadequate structural shielding. Insufficient structural protection, however, is a common cause of systemic damage. The systemic injuries include progressive changes in the blood forming organs and genetic injuries; the former result in anemia and lukemia while the latter may cause temporary or permanent sterility and, possibly, mutations affecting future generations.

As a result of more than a half-century of extensive research and experience, it is now possible to use Roentgen rays with a high degree of safety. Yet, even at the present time, adequate radiation safeguards are not universally employed; one still finds X-ray departments with insufficient or no structural shielding. In many cases, this is due to a false sense of security caused by the lack of early and obvious physiological changes associated with overexposure to radiation.

permissible exposure

The principle purpose in providing shielding against X-rays is to reduce unwanted or stray radiation to such a minute value that it has no known harmful effects on the human body. As this level, called permissible exposure (tolerance dose), has been progressively reduced, the expense of structural protection has steadily risen; it has now reached a point where it is an important factor in the construction cost of the X-ray department.

According to the recommendations of the National Committee on Radiation Protection, the maximum permissible exposure to X- or gamma-radiation from external sources is 0.3 Roentgen[2] (300 milliroentgens) per week. That is, it is considered safe to expose weekly the whole human body to this dose for an indefinite period.

It should be realized that it is impossible to eliminate exposure to ionizing radiations entirely; cosmic rays and the inherent presence of radioactive elements in the earth, the atmosphere, and in common building materials give a "background" exposure rate of about 0.01 mr/hr.

X-ray tube enclosures

The modern type of X-ray tube is enclosed in a protective housing, provided with a small aperture, practically limiting the rays to the useful beam. It should be emphasized, however, that although such equipment has been (erroneously) called "ray proof," it does not eliminate the need for structural shielding. Protective barriers must be provided against that part of the useful X-ray beam which is not absorbed by the patient and against secondary rays emitted by any material exposed to radiation.

protection barriers

The amount of structural protection required depends mainly upon the voltage used across the X-ray tube, the weekly milliampere-minutes (ma-min) of exposure, and the distance from the X-ray tube to the persons to be protected. The penetration of the X-ray beam increases considerably with the applied voltage, making the shielding requirements much greater for the higher potentials. As the quantity of X-rays is proportional to the milliampere-minutes, this consideration must be included in shielding calculations. Lastly, the intensity of the beam varies inversely as the square of the distance. This factor has a far greater significance than is generally realized; doubling the distance reduces the radiation to one quarter, tripling to one ninth, and so on.

Among the various metals suitable as barriers to the rays, lead is generally the most economical. Concrete and other heavy building materials may be used to advantage for voltages above 250 kv, where they are part of the structure as in floors and ceilings.[3] At voltages above 400 kv, concrete is used almost exclusively except where it is necessary to reduce the weight or space of the barrier. At 200 kv, a concrete barrier has to be about sixty times as thick as a lead barrier to give the same degree of protection; at one million volts, the ratio is only about six to one.

The thickness of a barrier also will depend upon the type of radiation to which it is exposed: the useful beam, leakage, or scattered (secondary) radiation. The barriers exposed to the useful beam are called *primary protective barriers* and their thickness may be determined directly from **Table I.** Leakage (also called direct) radiation describes the rays passing through the shielding of the tube housing. Leakage radiation varies greatly with the type and make of the tube housing; however, it generally does not exceed the values allowed by the latest protection code, or 0.1 r/hr for diagnostic and 1 r/hr for therapeutic tube housings, measured at one meter from the target of the X-ray tube.

The scattered radiation varies widely with field size and geometry; however, in fluoroscopy and radiography, it is safe to assume that at 90° it is less than one percent of the incident radiation measured at one meter (3.3 feet) from the scattering material. For 200-250 kv deep-therapy, this factor is less than 0.2 percent; and for one- to two-million volt therapy, less than 0.1 percent. Barriers exposed to leakage and scattered radiation only are called *secondary protective barriers.*

Consideration also should be given to the degree of occupancy of the space to be protected. Obviously, a stairway or lavatory requires less shielding than a permanently occupied office.

To summarize, the following factors must be known in order to determine accurately the protective requirements:

a. *Kilovoltage:* The maximum voltage rating of the proposed equipment.

b. *Milliamperage-minutes per week:* This factor depends both upon the milliampere rating of the equipment and the weekly work-factor. In fluoroscopy, the milliamperage is low, 5 ma or less, and the exposure time relatively long, perhaps 5 to 15 minutes per examination. In radiography, the current is high, up to 500 ma, but the individual exposure is short, mostly fractions of a second. In therapy, the current varies

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** Director of Physics Service, City of New York, Department of Hospitals.*

[1] *"Medical X-ray Protection up to Two Million Volts", (Handbook 41, National Bureau of Standards). Issued March 30, 1949; additions and corrections April 1950. Obtainable from Superintendent of Documents, Washington, D. C.; price 20 cents.*

[2] *Roentgen (r) is the international unit of quantity for both X- and gamma rays. The milliroentgen (mr) is 1/1000 r.*

[3] *Barium plaster has been used as a substitute for lead, also for lower voltage installations. However, as the barium plaster has to be applied very uniformly and as cracks may develop with age, its use has been practically discontinued in this country.*

Table 1—Primary Protective Barriers

Type of room	Kilo-voltage	Maximum weekly ma-min	*Distance from X-Ray Tube Target to Occupied Area*												*Approx. Half Value* layer	
			6 ft.		8 ft.		10 ft.		12 ft.		15 ft.		20 ft.			
			Lead mm	Conc. in.	Lead mm	Conc. in.	Lead mm	Conc. in.	Lead mm	Conc. in.	Lead mm	Conc. in.	Lead mm	Conc. in.	Lead mm	Conc. in.
adiography	100	500	1.2	3¾	1.0	3¼	0.9	2¾	0.8	2½	0.6	2	0.5	1½	0.2	¾
		2000	1.6	5¼	1.4	4½	1.3	4¼	1.2	3¾	1.0	3¼	0.9	3		
adiography	125	250	1.2	3¾	1.0	3¼	0.9	2¾	0.8	2½	0.6	2	0.5	1½	0.3	⅞
		1000	1.7	5½	1.5	4¾	1.3	4½	1.2	4	1.0	3½	0.9	3¼		
ierapy	100	2000	1.6	5¼	1.4	4½	1.3	4¼	1.2	3¾	1.0	3¼	0.9	3	0.2	
		8000	2.0	6¾	1.8	6	1.7	5¾	1.6	5¼	1.4	4¾	1.3	4¼		
ierapy	135	2000	2.1	7¼	1.9	6½	1.7	6	1.5	5¼	1.4	4¾	1.2	4¼	0.3	⅞
		8000	2.6	9¼	2.4	8½	2.2	8	2.0	7¼	1.9	6¾	1.7	6		
ierapy	200	20,000	5.0	13¼	4.6	12¼	4.3	11½	4.0	10½	3.7	9¾	3.3	8¾	0.5	1¼
		80,000	6.0	16	5.6	14¾	5.3	14	5.0	13¼	4.7	12½	4.3	11½		
ierapy	250	20,000	8.8	16	8.1	14¾	7.6	14	7.2	13	6.6	12	6.0	11¼	0.8	1½
		80,000	10.4	19	9.7	17¾	9.2	16¾	8.8	16	8.2	15	7.6	14		

from about 2 to 30 ma and the treatment may last from less than a minute up to an hour.

c. Distance: The shortest distance which is likely to be used between the X-ray tube and the occupied areas; the distances to neighboring buildings must also be known, if these are within the radiation field.

d. Occupancy: The degree of occupancy of surrounding regions.

e. Building construction: Frequently, the lead protection may be reduced or omitted by increasing the thickness of the building materials, especially in floors and ceilings.

construction of protection barriers

Handbook 41 gives the detailed construction requirements for protection barriers; it is necessary, therefore, to point out only the more common sources of error.

Special precautions should be taken to prevent scattering under lead-lined doors and barriers of a therapy room where the floor is not lead-lined. This may be accomplished by providing an 18″-wide lead saddle under the door-frame and by extending the wall lead-barrier into the floor; another method is to install a continuous 18″-wide strip of lead under the walls and door-frames *(see Figure 2)*. It may sometimes be necessary to provide shielding in the entire floor, even though there is no occupancy below, to prevent scattering under the lead-lined walls. Nearby buildings may possibly cause "back scatter" into occupied regions near the treatment room, necessitating shielding of the treatment-room windows.

Lead-glass windows should provide the same degree of protection as that required of the wall in which they are located. There should be adequate overlapping to prevent scattering around the glass.

A common error in structural protection is the lack of adequate support for the heavy lead-lined doors. Extra hinges and additional support for the door-frame should be provided.

special requirements: fluoroscopy

In fluoroscopy, protection is required against leakage and scattered radiation only, as the useful beam is almost completely absorbed by the lead-glass of the fluoroscopic screen. However, as fluoroscopic rooms are frequently used for radiography at a future time, it is advisable to provide the required additional protection initially.

radiography

In radiography, the useful beam is principally directed toward the floor or the wall area behind the patient when radiographed in an upright position. These areas, then, require primary protection barriers. To insure a higher factor of safety, permanently occupied regions, such as the control space and adjacent offices, should also have primary protection.

Special attention should be given to the protection of the operator; the most effective shielding will be achieved by locating the control of the X-ray equipment in an adjacent room provided with a lead-lined door. This is not always practical, however, as more than 100 radiographs may be taken daily in a busy X-ray room. Often, there is a tendency to leave the control door open during exposures. A lead-lined control booth without a door and within the radiographic room is satisfactory, if access is provided by means of a maze which effectively prevents scattering of radiation into the operator's position *(see Figure 1)*.

Undeveloped X-ray films are extremely sensitive to radiation and may be damaged by exposures of less than a milliroentgen. It is essential, therefore, that the darkroom have ample protection. Additional structural shielding may be avoided by storing the un-

Table 1a—Correction for Occupancy

Full occupancy (1) no reduction

Control space, residences, wards, offices, work rooms, dark rooms, corridors and waiting space large enough to hold desks, rest rooms used by the radiologic staff and others routinely exposed to radiation, and play areas.

Partial occupancy (¼) deduct 2 HLV

Corridors too narrow for future desk space, rest rooms not used by radiologic personnel, parking lots, and utility rooms.

Occasional occupancy (1/16) deduct 4 HVL

Stairways, automatic elevators, streets, closets too small for future work rooms, and toilets not used by radiologic personnel.

Table 2—Distances at Which Useful Beam Is Reduced to 300 mr/Week

Type of room	Kilo-voltage	Maximum weekly ma-min	Target distance feet
Radiography	100	500	85
		2000	125
Radiography	125	250	75
		1000	100
Therapy	100	2000	125
		8000	230
Therapy	135	2000	130
		8000	245
Therapy	200	20,000	360
		80,000	490
Therapy	250	20,000	385
		80,000	520

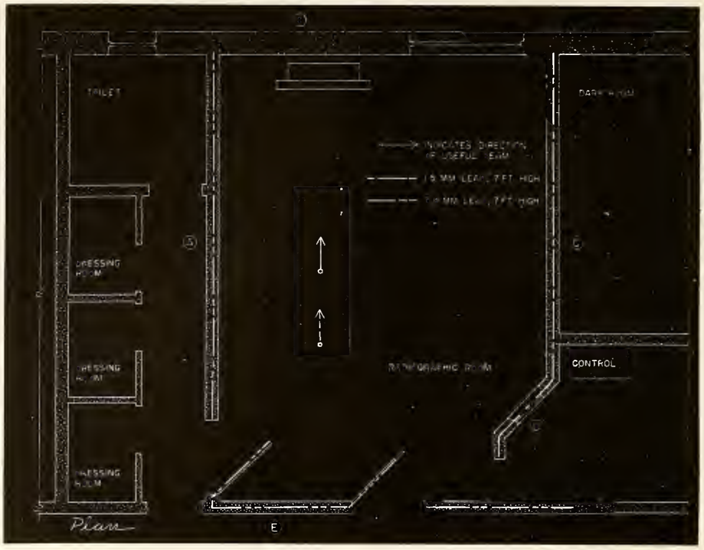

Figure 1—100 Kv Radiographic Installation, 2000 ma-min/Week

Position	Type of barrier	Distance feet	Barrier Thickness		Remarks
			Lead mm	Conc. in.	
A	Secondary	6	0.8	. . .	
B	Primary	20	. . .	3	
C	Primary	10	1.3	. . .	Dark room
D	Primary	10	1.3	. . .	Control
E	Secondary	8	0.7	. . .	
F	Primary	8	. . .	4½	Floor
G	Secondary	6	. . .	2¾	Ceiling

Note: Lead thicknesses on drawing are the nearest commercially available.

developed films in a lead-lined box, and by not directing the useful beam toward the darkroom.

therapy

Roentgen rays produced at potentials from a few kilovolts to several million volts are employed therapeutically at the present time. In the not-too-distant future, generators operating at many million volts may be used. There is a wide variation in the protective requirements of different types of therapeutic installations. Nevertheless, the aim is the same: to limit the radiation in all accessible locations outside the treatment room to the maximum permissible value of 0.3 Roentgens per week.

location of therapy rooms

The cost of structural shielding may be reduced materially by locating the treatment rooms at some distance from habitually occupied regions, taking advantage of the "inverse square" law. As the useful beam is directed most frequently toward the floor, considerable saving may be gained by avoiding occupancy directly below the treatment room. This is particularly true for high voltage installations; further economy may be obtained by utilizing corner rooms where possible. Outside walls and especially windows may require radiation barriers, if they are close to occupied regions. This is apparent from a study of **Table 2** wherein distances required to reduce dosage rates to permissible values are shown for various conditions.

The control of the X-ray generator should be located outside the treatment room if voltages above 100 kv are used; further, the doors to the treatment room should be provided with electrical interlocks, preventing exposure when open.

shielding

Unless the orientation of the useful beam is restricted, primary protection barriers should be provided in the entire floor and all the inside walls up to a height of seven feet. Where the location of the X-ray tube is fixed, it is possible to limit the primary shielding in the floor to the area actually exposed to the useful beam plus a border-strip one-foot wide. This saving is not recommended where there is a possibility of later changes in the location of the tube stand. Primary protection is usually not necessary in the ceiling, as the required secondary protective barriers are adequate to permit occasional therapy with the useful beam directed upwards. As previously mentioned, even outside walls and especially windows may require shielding. This is particularly true where treatment rooms face a narrow court. A solution for the protection barrier requirements of a 250 kv therapy installation is illustrated *(Figure 2).*

scattered radiation

The most frequent cause of inadequate protection is insufficient shielding against scattered rays emitted by the patient, floors, walls, or other irradiated objects. The intensity and quality of the scattered radiation vary with the size of the field, angle of scattering, and the nature of the scattering object. Furthermore, the intensity depends also upon the dosage rate of the incident beam and the distance from the scattering object.

one- and two-million volt installations

The safe and economical construction of installations in this voltage range requires considerable individual planning and expert advice; it is not possible here to give detailed information which is generally applicable. There are, however, certain general principles which should be mentioned, while additional data may be obtained from two recent papers.[4]

The cost of shielding such installations is determined largely by their location. Great savings may be gained by taking full advantage of the "inverse square law" in reducing the radiation. Wherever practical, a maze should be used as access to the treatment room, rather than a heavy motor-driven lead or steel door, the cost of which may exceed $10,000. If possible, the orientation of the X-ray tube should be so restricted that the maze entrance, or door, and the operator's position are not exposed to the useful beam.

Observation of the patient may be accomplished through a transparent tank filled with water and covered with lead-glass on the side facing the operator. The observation window should offer the same degree of protection as that required of the wall in which it is mounted. The concrete, protective equivalent of such a window is approximately equal to one-third of the thickness of the water barrier plus twice the thickness of the lead-glass.[5] The two sides, the top and bottom of the tank should be lined with at least ¼" lead overlapping the lead-glass window to prevent scattering around the window.

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[4] *"Radiology 51,840" (1948); C. B. Braestrup and H. O. Wyckoff. "Radiology 51,849" (1948); H. O. Wyckoff, R. J. Kennedy, and W. R. Bradford.*

More recently, observation windows using laminated, ordinary glass have been used. However, the total thickness of the glass has to be sufficient to give the same lbs/sq. ft. as that required for concrete wall.[6]

calculation of barrier thickness

The National Bureau of Standards Handbook 41 has extensive tables and charts for the determination of the barrier thicknesses. They may be very much simplified by considering only those operating conditions which are commonly used.

In **Table I** are shown the required thicknesses of primary protective barriers for the usual range of milliampere-minutes used per week. The minimum values are applicable for the smaller, less active hospital, while the maximum values should be used for any institution with a busy radiological service.

The determination of the thickness of a secondary protective barrier is more complicated, as it involves a larger number of factors. However, a usually safe approximation may be made by assuming that the secondary barrier requires one-half of the thickness of a primary protective barrier, again using the values of **Table I.**

The thickness of both primary and secondary barriers may be reduced above seven feet, as the rays are rescattered or passed through the ceiling of the adjoining room before striking any occupants. Both processes result in considerable attenuation of the radiation; and the barrier thickness above seven feet only needs to be one-third or one-quarter of the primary protective barrier thickness. For voltages not exceeding 125 kv, no lead shielding is required above seven feet, as the wall itself offers enough protection. X-ray protection measurements of numerous representative hospital installations have established that the above empirical rules provide adequate shielding. Greater economy may be obtained by a more complete analysis of all the factors involved, but the methods used for such determinations are usually too involved to be of value to the architect.

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[5] *The actual protective equivalent of the window will also depend on the area of the window and quality of the lead glass.*

[6] *As the density of glass is higher than that of concrete, the thickness of glass can be reduced in the ratio of the density of concrete to glass. For example, if a glass has a 10-percent higher density than concrete, the thickness of the glass window can be 10-percent less than the thickness required for a concrete wall, acting as a protection barrier.*

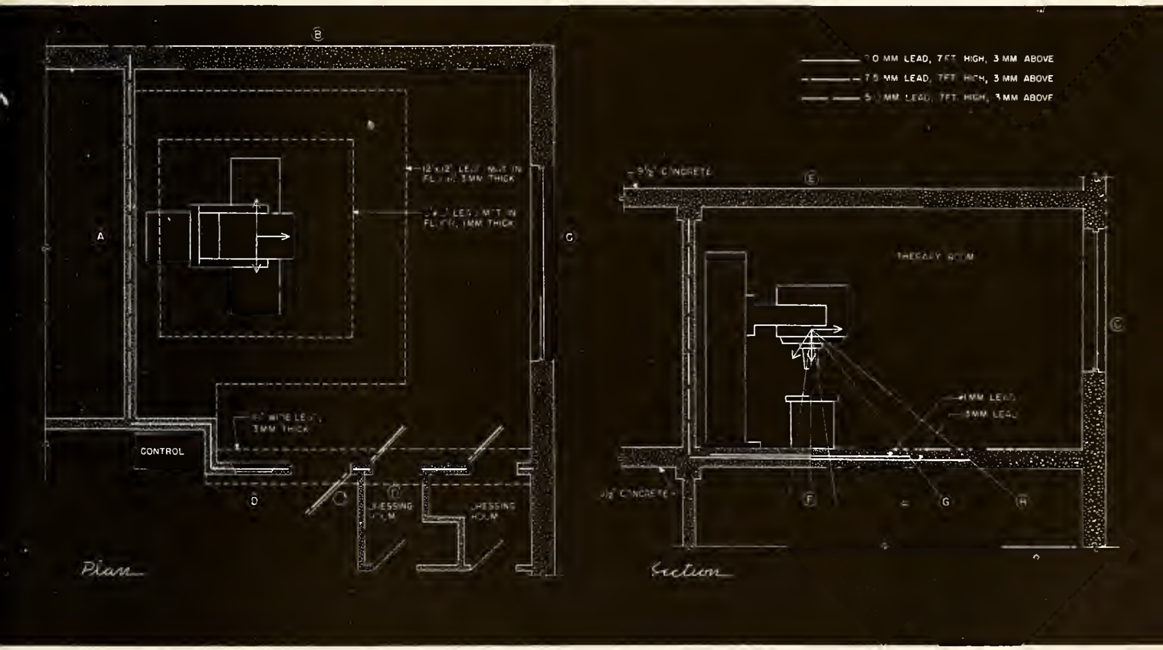
B
A
12'x12' LEAD MAT IN FLOOR, 3MM THICK
LEAD MAT IN FLOOR, 1MM THICK
C
WIDE LEAD, 3MM THICK
CONTROL
D
DRESSING ROOM
DRESSING ROOM
Plan
0 MM LEAD, 7 FT HIGH, 3 MM ABOVE
7.5 MM LEAD, 7FT HIGH, 3 MM ABOVE
MM LEAD, 7FT HIGH, 3MM ABOVE
9½" CONCRETE
E
THERAPY ROOM
C
1MM LEAD
3MM LEAD
CONCRETE
F
G
H
Section

Figure 2—250 Kv Therapy Installation

Position	Ma-min per week	Type of barrier	Distance feet	Barrier Thickness		Remarks
				Lead mm	Conc. in.	
A	80,000	Secondary	6	5.2	...	
B	20,000	Primary	20	...	11¼	
C	20,000	Primary	385	...	...	
D	80,000	Primary	10	9.2	...	
D[1]	20,000	Primary	10	7.6	...	
E	80,000	Secondary	6	...	9½	
F	80,000	Primary	10	4.0 plus	9½	
G	80,000	Primary	12	3.0 plus	9½	Oblique path = 11½"
H	80,000	Primary	15	...	9½	Oblique path = 14¼"

Hospital Radioisotope Laboratories

BY CARL B. BRAESTRUP AND EDITH QUIMBY*

The use of radioisotopes in diagnosis and therapy has passed the experimental stage and is now routine in many hospitals. Since the safe and efficient employment of radioisotopes requires adequate laboratory facilities, it is important in the planning of new hospitals to determine whether they are likely to be used.[1]

While not all hospitals require isotope laboratory facilities at the present time, it may in many cases be advantageous at least to make arrangements for their future installation without expensive alterations. It is not possible here to generalize as to what hospitals should provide the use of isotopes. It is not merely a question of size; it depends on local conditions, such as the availability of qualified specialists and the avoidance of duplication of nearby facilities.

The architect planning a hospital isotope laboratory needs the following information:

(1) Number of rooms required and approximate floor space.
(2) Preferred location in hospital and location of individual laboratory rooms in relation to one another.
(3) Special requirements: a) structural gamma ray shielding; b) ventilation; c) plumbing; d) floor loading.
(4) Built-in equipment: hoods, fixed laboratory benches, cabinets.
(5) Detailed requirements: type of walls, floor and ceiling finish, size of doors, electrical outlets, etc.

The answers to these questions depend, to a large extent, upon the scope of the isotope program; that is, the type and the amount of isotopes to be used, and the nature of the clinical program.

The requirements of the radioisotope laboratory devoted mainly to research vary widely, and the architect usually has the advice of the scientists who are going to direct its activities. It is, therefore, not necessary here to consider the design of such specialized facilities. The purpose of this report is to provide the information required for planning the average hospital laboratory to be used primarily for hospital work. It is assumed, therefore, that the minimum facilities should permit the safe handling of the following isotopes: iodine, iron, gold, phosphorus, and cobalt *(as listed in Table I)*. Some of the data in this report have already been published[2] and more detailed information may be obtained from several Atomic Energy Commission and National Bureau of Standards reports.[3, 4, 5, 6, 7]

ROOMS REQUIRED AND FLOOR SPACE[8]

The laboratory should generally consist of at least three rooms *(as shown in Figures 1, 2, and 3)*.

(1) The high activity radiochemical laboratory for the handling and preparation of large amounts of isotopes, up to several hundred millicuries; this room should not be less than 150-200 sq ft. Directly connected with the radiochemical laboratory should be a storage space for radioactive isotopes and specimens; a closet 4 ft x 4 ft will usually suffice.

(2) A measuring or counter room for the assay of radioisotopes and the measurement of excretions and specimens for radioactivity, with minimum floor space 120-150 sq ft. This room may possibly be used also for up-take measurements on patients *(as shown in Figure 5)*, although it is preferable to do this in a separate room.

(3) Patients' up-take measurement room. This room is used to determine (usually by means of Geiger or scintilla-

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* *Associate Professor Radiology (Physics), Department of Radiology, Columbia University, New York, New York*

[1] *Certain isotopes like cobalt-60 and cesium-137 usually do not require laboratory facilities; however, if used in teletherapy in place of supervoltage X-ray equipment, extensive shielding is required for the treatment room. The requirements vary widely according to location, etc.; an expert's advice is usually required to insure adequate protection at minimum cost.*

[2] *Quimby, Edith and Braestrup, Carl B.: "Planning the Radioisotope Program in the Hospital."* The American Journal of Roentgenology and Radium Therapy, *Vol. LXIII, No. 1, January 1950.*

[3] *Ward, Donald R.: "Design of Laboratories for Safe Use of Radioisotopes." Advisory Field Service Branch, Isotope Division, Atomic Energy Commission, Oak Ridge, Tenn., 1951.*

[4] *National Bureau of Standards Handbook 42. "Safe Handling of Isotopes." (Obtainable from Superintendent of Documents, Washington, D.C.)*

[5] *National Bureau of Standards Handbook 48. "Control and Removal of Radioactive Contamination in Laboratories and Hospitals."*

[6] *National Bureau of Standards Handbook 49. "Recommendations for Waste Disposal of P-32 and I-131 for Medical Uses."*

[7] *Building Research Advisory Board, Research Conference Report No. 3. "Laboratory Design For Handling Radioactive Materials." Sponsored by The American Institute of Architects and the Atomic Energy Commission, November 1951.*

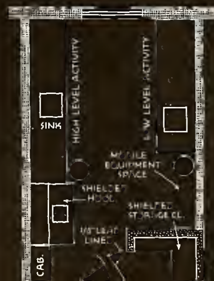
[8] *Prepared isotopes ready for use are likely to be more readily available from commercial sources in the future. This will tend to reduce the required laboratory facilities.*

Figure 1—radiochemical laboratory. Where an active radioisotope program is planned, it may be advisable to divide this laboratory into two rooms—one for low-level activity and one for high-level activity.

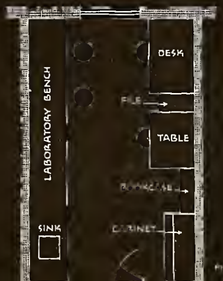
Figure 2—assay of radioisotopes and office. Only low-level isotopes are used in this room. Where space permits, it is desirable to have a separate room for office.

Figure 3—Patients' up-take measurement room. The door to this room should be sufficiently wide to permit the entrance of patients' beds. This room is used also for the administration of radioisotopes to patients.

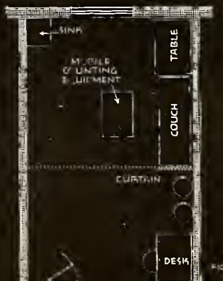
Figure 4—small isotope laboratory-radiochemical laboratory. Shielded cabinet replaces closet for radioisotope storage.



FIGURE



FIGURE



FIGURE

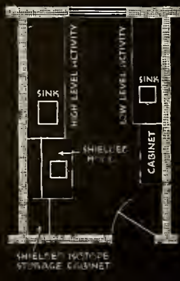


FIGURE 4

tion counters) the location and amounts of radioisotopes taken up by the patients after administration. The minimum satisfactory floor space is 120-150 sq ft. It should be so arranged that a stretcher can be brought into the room and should have additional space for a couch, movable table, and counting equipment.

LOCATION

In deciding upon the location of these rooms, first consideration should be given to their accessibility to the service most closely associated with the isotope program. In general, the radiochemical laboratory should be near the clinical laboratories, and readily accessible to the radiotherapy department, if its staff is responsible for the isotope service. Furthermore, where space is very limited the radiochemical laboratory may serve also as a radium preparation room. A top floor location of the radiochemical laboratory has the advantage of simplifying the exhaust of the isotope hood, since this cannot be connected to the general hospital ventilating system. On the other hand, a basement or ground floor location may permit the drains of the laboratory sinks to be connected directly to the main soil line of the hospital, thereby minimizing contamination of the local plumbing. This, however, is a minor consideration unless large quantities of isotopes are used.

The patients' measuring room should be readily accessible to both in- and out-patients and it need not be near the radiochemical and measurement laboratories. The measuring and the patients' up-take rooms should be located at some distance from intense sources of radiation, unless adequate shielding can be provided. On the other hand, these rooms, especially the measuring room, should not be too far from the radiochemical laboratory, in order to minimize the possibility of contamination of intervening halls and to eliminate unnecessary steps for the technician. At the Francis Delafield Hospital (New York City), both a high degree of shielding and easy communication have been obtained by placing the radiochemical laboratory on the floor below the measuring room and using dumb-waiters for the transfer of the radioactive materials *(illustrated schematically Figure 6)*.

SPECIAL STRUCTURAL REQUIREMENTS

gamma ray shielding

The question of structural gamma ray shielding has been the subject of a great deal of controversy. Twenty-four-inch concrete walls have been recommended by some physicists, while others advocate the use of shielding around the individual radiation sources only. The subject may be considered from two angles: (1) health hazards; (2) radiation affecting instruments.

Structural Shielding for Reducing Health Hazards

Obviously little is gained in providing structural shielding against gamma ray sources located in a room which is occupied eight hours a day by the same persons. On the other hand, rooms such as storage rooms, which are occupied only for a short time, may be shielded to advantage. For instance, individual shielding around the sources might permit one hour per day occupation inside the storage room while structural shielding allows eight hours occupancy outside it.

The amount of structural shielding depends on the isotopes used. To increase permissible exposure time from one hour to eight, without increasing the distance, requires the interposition of three half-value layers of shielding material. For iodine-131 this is 6½ in. of concrete, for sodium 24 it is 13 in. *(See Table 1.)*

Structural Shielding for Reducing Background

In using radiation measuring instruments, the maximum acceptable radiation level above normal background is usually 0.01 mr/hr or less. To attain this level in measuring rooms structural shielding may be justified, although the same reduction often may be obtained by increasing distance from sources of radiation and by the use of shielding around sources and counter tubes. When providing structural shielding, consideration should be given not only to the walls, floor, and ceiling but also to doors. As was shown *(Figure 1)*, a shielded storage room can be so arranged that the radiation passing through the door is scattered before

Figure 5—combined radioisotope assay and patients' up-take measurement room.

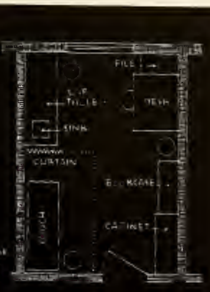
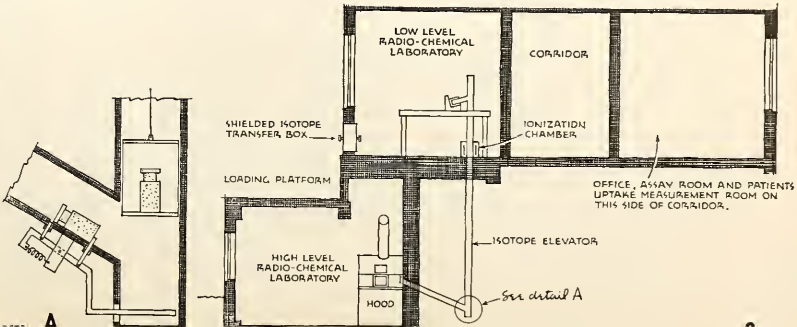


FIGURE
5

Figure 6—automatic handling of isotopes. The isotopes are prepared and bottled in hood in basement. Bottles are placed in inclined tube and automatically loaded on dumbwaiter car. Each time car reaches bottom it picks up one bottle; stops in center of ionization chamber are made for check measurements. At top, bottle is ejected from car and slides into lead container.


LOW LEVEL RADIO-CHEMICAL LABORATORY
CORRIDOR
SHIELDED ISOTOPE TRANSFER BOX
IONIZATION CHAMBER
LOADING PLATFORM
OFFICE, ASSAY ROOM AND PATIENTS UPTAKE MEASUREMENT ROOM ON THIS SIDE OF CORRIDOR.
ISOTOPE ELEVATOR
HIGH LEVEL RADIO-CHEMICAL LABORATORY
HOOD
See detail A
A

reaching working areas, thus reducing the necessary shielding of the door. The main objection to extensive structural shielding is, in addition to its cost, the permanency which prevents future changes in the laboratory layout.

When the measuring rooms must be near the radium or X-ray therapy rooms, the possible need of structural shielding must be considered. The distance from a radium source at which the radiation will be 0.01 mr/hr is determined by the formula:

$$\text{Distance (in feet)} = \sqrt{30 \text{ mg of RA}}$$

(Assuming no shielding.)

However, the hospital radium supply is usually shielded so that the dose rate outside its safe or its preparation room is not more than 6.25 mr/hr. A reduction factor of 625, or an increase in distance of 25 times is necessary to reduce the dose rate to 0.01 mr/hr. This can usually be arranged for the radium where the distance from the source to the 6.25 mr/hr level is only a few feet. However, for X-ray rooms, when the distance from the target to the position of 6.25 mr/hr may be of the order of 8 feet, the distance from the X-ray room to the measuring room would have to be 200 feet and this may be impracticable. Intervening walls may offer considerable shielding but the final reduction may have to be made by a local shield around each counting tube.

ventilation

The hood of the radiochemical laboratory should be provided with a separate exhaust to the outside. The exhaust should terminate at a distance from occupied areas; it is, therefore, usually necessary to provide a duct terminating above the roof, to prevent discharge near windows or air

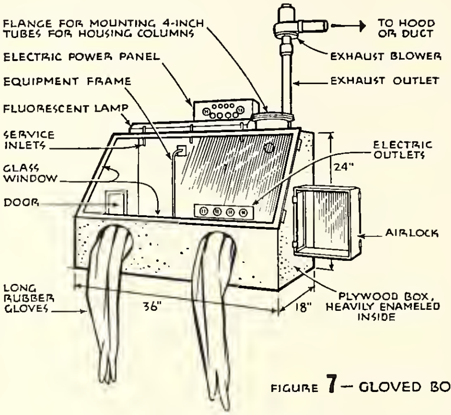


FIGURE 7 — GLOVED BOX

TABLE I: COMPARISON OF RADIOISOTOPES

	Half-life	Beta radiation				Gamma radiation				
		Maximum energy mev	Completely stopped by water mm	pyrex mm	air cm	Energy mev	r/mc hr at 1 cm	"Danger range" for 1 mc	H.V.L. cm Pb	Approx. H.V.L. concrete
Bromine ${}_{35}\mathrm{Br}^{82}$	34 hrs	0.465	1.4	0.7	115	0.547 0.787 1.35	15.1	49.2 cm 19.4 in.	1.3	6.6 cm 2.6 in.
Carbon ${}_{6}\mathrm{C}^{14}$	5100 yrs	0.15	0.2	0.1	16		None			
Cobalt ${}_{27}\mathrm{Co}^{60}$	5.3 yrs	0.31	0.8	0.4	62	1.1 1.3	13.6	46.6 cm 18.4 in.	1.2	6.3 cm 2.5 in.
Gold ${}_{79}\mathrm{Au}^{198}$	2.7 days	0.98	4.0	1.8	380	0.12 0.41	2.4	19.6 cm 7.7 in.	0.31	4.5 cm 1.8 in.
Iodine ${}_{53}\mathrm{I}^{131}$	8 days	0.60	2.0	1.0	160	0.080 0.367	2.65	20.6 cm 8.1 in.	0.28	4.1 cm 1.6 in.
Iron ${}_{26}\mathrm{Fe}^{59}$	46 days	0.46	1.4	0.7	115	1.1 1.3	6.55	32.3 cm 12.7 in.	1.3	6.6 cm 2.6 in.
Phosphorus ${}_{15}\mathrm{P}^{32}$	14.3 days	1.7	8.0	3.5	620		None			
Potassium ${}_{19}\mathrm{K}^{42}$	12.4 hrs	3.5	17.5	7.9	1800	1.51	1.95	17.7 cm 7.0 in.	1.4	7.3 cm 2.9 in.
Radium ${}_{88}\mathrm{Ra}^{226}$*	1560 yrs	3.15	15.6	6.9	1550	0.047 0.19 1.8 2.2	8.4	36.7 cm 14.5 in.	1.3	6.6 cm 2.6 in.
Sodium ${}_{11}\mathrm{Na}^{24}$	14.8 hrs	1.4	6.4	2.8	500	1.4 2.8	19.1	55.3 cm 21.8 in.	1.7	8.8 cm 3.5 in.
Sulphur ${}_{16}\mathrm{S}^{35}$	87 days	0.17	0.2	0.1	16		None			

NOTE: The "danger range" is the distance at which the dosage rate is 6.25 mr/hr (or 0.3 r/week for 48 hours weekly exposure).

Attenuation factor to reduce dose rate to 6.25 mr per hour at any distance $= \dfrac{(\text{Danger range})^2}{(\text{Distance})^2} \times \text{mc}$.

* In equilibrium with its decay products

intake ducts. The blower should be located near the discharge end of the duct in order that any leakage of the duct will not cause contaminated air to be blown into occupied areas. The blower motor should be mounted outside of the duct to prevent contamination of the motor and to facilitate repairs. The blower should have sufficient capacity to give an air velocity of about 75 ft/min at the face of the hood with maximum openings. A damper should be provided at the hood to reduce the air flow to any required value.

Air conditioning is recommended for the measuring rooms, but not for the radiochemical laboratory, where it would be very wasteful due to flow of air into the hoods.

special facilities

No special facilities are required except the usual laboratory sinks. No floor drains are needed. An emergency shower is recommended if large amounts of isotopes are handled; this should be near or in the radiochemical laboratory. Most industrial plants handling radioactive materials have provisions for the workers to take showers and change clothes before leaving the premises. Similar facilities have been advocated for hospital isotope laboratories; however, the possibility of general body contamination is remote in a well-supervised hospital isotope laboratory, and ordinary dressing room facilities are all that are necessary. Stress should be put on preventing contamination rather than on clearing it up afterwards.

floor loading

Special attention should be given to the floor construction to insure adequate carrying capacity. Lead-shielded hoods may weigh more than a thousand pounds, and in addition the floor must be able to support mobile shields weighing several hundred pounds.

BUILT-IN EQUIPMENT

The fixed equipment and facilities of the radiochemical laboratory vary greatly with the type and quantity of isotopes used. It is advisable at least to provide space for a chemical fume hood designed especially for the handling of radioisotopes. The hood may not be required initially if only rather small amounts of isotopes are used and there is no drying of radioactive materials. Isotope hoods may be divided into two general types: those which provide built-in gamma ray shielding and those which depend entirely on shielding around the radioactive sources. In a busy isotope laboratory it may be desirable to have one of each type, the shielded type for gamma ray emitters and the unshielded one mainly for isotopes emitting beta radiation only. It is not always practicable to provide sufficient shielding of the hood to give complete gamma ray protection, since this may require lead several inches thick for such istopes as Na^{24}. Instead, barriers of lead bricks may be placed around each radioactive source; the shielding of the hood then serves mainly to absorb the scattered radiation, which is much more readily attenuated, due to its lower energy. A typical shielded hood for hospital isotope work has two sliding lead panels that provide openings for the hands and at the same time double the shielding thickness in front of the technician when it is needed the most. It is generally recommended that the hood be lined with ½-in. lead. The double thickness in front (one in.) gives adequate protection (6.25 mr/hr for 500 mc of I^{131} at a distance of one ft). The ½-in. lead will give a similar degree of protection at four ft. Where Na^{24} is used, it is necessary to provide additional shielding around the source if the amount is more than one mc. It should be emphasized here that the hospital shielding requirements are considerably less than those used on most Atomic Energy Commission projects where kilocuries may be handled. On the other hand, the better the shielding of the hood, the less is the dependence on proper arrangement of movable barriers.

Frequently too little consideration is given to the protection of people on the other side of the wall near the hood or storage space. The ordinary cinder block partition offers very little attenuation of the type of gamma radiation ordinarily present. Considerable shielding economy may be gained by placing the hood against a wall which has no occupancy on the other side; for example, against an outside wall, where usually no shielding is required, due to the greater distance to occupied regions.

Where feasible, provisions should be made for the remote handling of radioactive materials. Effective manipulators have been devised, but such elaborate equipment will be necessary only where large gamma ray emitting sources are handled routinely. Simpler devices will suffice in most hospital isotope laboratories. Where possible, sufficient shielding should be provided to stop all the beta radiation at the source. The thickness required is indicated *(Table 1)* for the more commonly used isotopes. When handling isotopes which are beta emitters only, the main problem is to prevent contamination. A "glove box" *(Figure 7)* permits carrying out experiments without actual contact with apparatus which may be contaminated, and which provides protection against soft beta emitters such as C^{14} and S^{35}.

The radiochemical laboratory should have a chemical laboratory bench provided with the usual facilities such as a sink, gas, air, and electrical outlets. This bench should preferably have a stainless steel top with raised edges to prevent overflow and contamination of the worker in case of spills. The same end may be achieved by keeping all equipment on stainless steel trays during use. The occupancy of the radiochemical laboratory should be restricted to that actually required in conjunction with the isotope work, in order to minimize the exposure of the personnel to radiation. This may be encouraged by limiting other equipment and furniture to a minimum.

The measuring room does not require any fixed equipment except a laboratory sink and a suitable array of electric outlets, movable tables for measuring instruments allow greater flexibility than built-in furniture. On the other hand, a laboratory bench *(shown in Figure 2)* requires less space and offers the convenience of semi-permanent electrical installations. Air conditioning is desirable, especially where the summer climate is very damp, in order to insure better operation of electrical equipment.

DETAILED REQUIREMENTS

All exposed surfaces of the radiochemical laboratory should be smooth and nonporous to minimize contamination. Uncovered wood and concrete floors are not desirable. Linoleum and particularly tile offer satisfactory floor covering, as they can readily be replaced in case of serious contamination. Strippable coatings of the "vinyl base" type should be used on wall surfaces likely to become contaminated, as it can easily be peeled off.

In conclusion, it should be pointed out that the medical applications of radioisotopes are still growing. It is important, therefore, that the laboratory layout be sufficiently flexible to permit future changes and expansion.

Weather-Conditioning of Roofs for Residences

BY GROFF CONKLIN

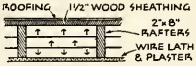
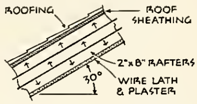
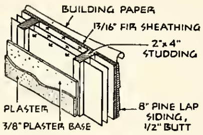
One of the most controversial and confusing aspects of modern home design is the achievement of control over the relation between exterior and interior climates the year round. This is a problem with which every architect must cope, whether he is designing a luxury residence or a five-room bungalow. It should be stated at the outset, that the exclusion of foundations and exterior walls from this review does not mean that these components of the dwelling are not as integral a part of the climate control problem as they are of the house itself. However, the roof and the attic below it present a number of special and complex technical questions which do not necessarily enter into the design of the rest of the house, and for this reason they must be considered as a separate and distinct part of the over-all problem. Traditionally, a home used to be considered well-built if it offered complete protection against the entry of wind, rain, snow, and dust, was sturdy and durable in materials and in construction, and barred entry to the more obvious hazards of the living external environment such as insects, rodents, and human prowlers. Such construction was accepted as the best that could be had by even the wealthiest client. The concept of the house itself as an *active* protection against winter cold and summer heat was unheard of. One heated the dwelling with a furnace, and if half the heat escaped through the roof and walls that was an unavoidable and universally accepted part of home operating costs. In summer one opened the windows, used palm-beach fans, and drank cool drinks to combat the sweltering heat; the owner of an all-stone house thought himself fortunate because the walls did help to keep the interior somewhat cooler than those of a frame house. In all types of dwellings the attic was always an efficient summer heat trap.

With the advent of modern insulating materials the whole art and science of residential design and construction took a revolutionary turn, bringing with it a number of problems that even today baffle a considerable portion of the profession. It is difficult, actually, to realize how recently both "convection insulation" (an excellent term used by C.-E. A. Winslow, Yale School of Medicine, for bat, blanket, or fill-type insulating materials), and reflective or radiation insulation have become standard parts of house construction. As recently as 1933, Bemis and Burchard, authors of a three-volume work called *The Evolving House* (published by Massachusetts Institute of Technology), in describing "suburban construction," referred only in passing to "lath . . . of heat-insulating material to cut down the fuel bill." They omitted all reference to insulation in their index, and showed in their wall cross-sections an empty air space between outer and inner surfaces of the structure.

Today, however, hardly a house is built, at least in the northern parts of the country, without some sort of insulation against cold. America's home buyers have become accustomed to demanding it in the attic and walls of the dwellings they purchase. For, even considering its defects and the maintenance problems which often follow upon poorly-designed and haphazardly installed materials, insulation always results in sizable savings in heating costs.

But insulation can be a much more effective barrier against cold and heat than it usually is today. In winter, the extremely serious difficulties caused by moisture condensation behind insulation may be to all intents and purposes eliminated by up-to-date materials and construction practices. In summer, the control of the sun's radiant heat by use of reflective insulation, either alone or in combination with the convective type, can help to create genuinely comfortable living conditions during even the hottest spells.

It is the purpose of this article to describe the various ways in which these goals may be attained through the correct design and installation of

		Heat flow	U	C_1	Temperatures ΔT for C_1
First test		Up	0.11 0.12	0.16 0.17	25 45
		Down	0.05 0.06	0.06 0.07	25 45
Second test		Up	0.11 0.12	0.14 0.17	25 45
		Down	0.07 0.08	0.09 0.10	25 45
					Air Temperatures
Third test		—	0.08 0.08	0.12 0.11	70 30 70 100

U, transmittance of roof or wall
C_1, conductance of air space, plaster base to sheathing
The U values shown are for an inside surface coefficient of 1.65 and an outside coefficient of 6.00, corresponding to a 15 mph. wind.

TABLE 1: ROOF AND WALL COEFFICIENTS WITH ALUMINUM INSULATION.

From "Transactions A.S.H.V.E., Vol. 46, 1940."

different types of insulation, vapor barriers, means of ventilation, and certain special elements having particularly to do with summer heat controls in the attic and the roof.

Let us consider then the essential components of a well weather-conditioned roof. No problem presents itself, of course, in designing roof structures to withstand the *force* of the elements. The problem is not one of strength, it is, rather, one of thermal control.

Insulation

The first and most important factor in a weather-conditioned roof is its insulation, and here it is that one finds some of the most violent controversy in the building industry. The issue at base revolves around the question whether convective insulation with vapor barrier, reflective insulation with adequate "dead air" spaces, or a combination of the two, is the most efficient and, in the long run, the most economical method of stabilizing the exterior-interior temperature and moisture relationships in regions of wide climatic variations.

Bearing in mind that laboratory tests may be inaccurate reflections of the actual performance qualities of a material, the following data may still be studied with some profit:

1. From Wilkes, Hechler and Queer, *Transactions of the American Society of Heating and Ventilating Engineers, Vol. 46, 1940,* come these figures for the U-factor, or over-all coefficient of heat transmission in typical roof and wall constructions containing two layers of reflective insulation. The insulation material consists of one layer with aluminum foil on both sides, and a second layer foiled only on one side. Thus, in a roof with 8" rafters, there are three reflective surfaces, with a 2.7 inch air space between each layer, as well as between the top layer and the roofing, and the bottom layer and the lath and plaster (see Table 1). The first test, for a horizontal roof, gave U-factors of 0.11 and 0.12 for upward-moving heat, and 0.05 and 0.06 for downward-moving heat. The second test for a similar construction tilted 30° from the horizontal to simulate a pitched roof, gave U-factors for upward heat flow which were the same as for the horizontal panel. For downward heat flow they were 0.07 and 0.08—slightly higher than for the horizontal section. The third test was for a vertical wall section constructed to simulate a standard wall in a frame house. Here the U-factors were 0.08 and 0.08, there being no "upward" and "downward" to contend with.

2. From Rowley and Lund, *Transactions of the American Society of Heating and Ventilating Engineers, Vol. 49, 1943,* have come these U-factors for walls with 2" x 6" joists, mineral wool bat insulation, and an inner face of ⅜" gypsum plaster board. With nominal 3" bats, measured thickness of 2.646" and density of 2.24 lbs. per cu. ft., this wall held horizontal had a U-factor of 0.106 for upward moving heat; held vertical, a factor of 0.102. In both tests a bat with a vapor barrier on one side was furnished. With nominal 4" bats with vapor barriers, actual measured thickness being 3.89" and density of 2.99 lbs. per cu. ft., a U-factor of 0.084 was obtained for upward moving heat, and a factor of 0.088 when the wall was held vertical.

These figures indicate that for the samples tested there was relatively little to choose between the convective and reflective insulations for upward and laterally moving heat. For downward moving heat, however, it will be noted that reflective insulation possesses a remarkably low overall coefficient of heat transmission.

Today there are available regular reflective insulations consisting of either two or three layers of pure aluminum foil, reflective both sides, and separated by air spaces. They are designed so that when the strips are installed the layers are between 1" and 2" apart. The U-factors claimed are at least equal to those found in Table 1. Reflective foil combinations, when correctly made and installed, have something of a future in the insulating business, particularly as a means of controlling summer temperatures inside the house as well as efficient and adequate winter insulation.

There are a number of considerations which the architect must regard in selecting an insulation. Here are some of those affecting reflective insulation:

1. According to Wilkes of Massachusetts Institute of Technology, a normal layer of dust on the surface of a reflective foil does *not* materially decrease its insulative value. The infrared rays, which make up most of the radiant heat one wants to keep in the house in the winter and out of the house in the summer, are reflected back nearly as efficiently with the layer of dust present as without. Consequently, the dust that may settle on the reflective foil in an attic installation is inconsequential in its effect on the material's insulating value.

2. Reflective insulating foils are at one and the same time nearly perfect vapor barriers, according to Dill of the Bureau of Standards and various other responsible scientists. No other barrier is needed. (See vapor barriers discussed further on in this article.)

3. However, if aluminum foil comes in contact with wet plaster or mortar it corrodes easily. Consequently, care must be taken in installing this insulation to keep it from contact with such materials. The insulation should be installed between framing members, and not across their faces, if a plaster surface is to be added as an inside finish. This may involve a somewhat higher labor cost.

4. The heat storage capacity of reflective insulation is low. As a result, it does not store heat during summer days, only to pass it on down into the rooms of the house from the attic at night when coolness is most apt to be desired from the point of view of sleeping comfort.

The conclusion from these various facts is that, at least as far as present knowledge goes, reflective insulation is one of the essentials for a weather-conditioned house in a region that has hot summers. Whether it is as good, or better, than the convective insulations for winter use is still to be ascertained by scientific testing on comparable bases, and by actual practice in occupied dwellings. Convective insulations, with their extremely small reflective insulating values, are not as effective in reducing summer heat.

Some of the considerations, in the case of convective insulations in general, which the architect should bear in mind follow:

1. The cost factor in most standard mineral wool and fiber insulations may tend to make them preferable, at least for the time being, to the reflective type, though the prefabricated aluminum foil units described above are claimed to be competitive in price with mineral wool insulation of the same C-factors and a good vapor barrier on one side.

2. Installation is likely, at present, to be less expensive as well, since mechanics are more accustomed to working with these materials than with the reflective insulations. No care has to be taken to suspend the convective insulations so they will not make contact with the inner or outer layers of the structure, as has to be done with the reflective insulations if they are to be of full value.

3. The propensity of convective insulations to absorb heat markedly reduces values as insulations for summer comfort, making them considerably less effective for this purpose than aluminum foil and other reflective surfaces.

4. Certain types of convective insulations, though not all, absorb and hold moisture with increasing interior relative humidity and falling exterior temperatures. They thus lose much of their insulating value. Furthermore, this moisture accelerates compaction of the "three-dimensional" insulations which depend on minute air spaces in their cross-sections for their effect. This further decreases their efficacy as time passes and parts of the house become to all intents uninsulated. Vapor barriers, of course, will slow down or actually stop this tendency.

vapor barriers

There can be few architects today who are unaware of the existence of the problem of moisture condensation in insulated homes. Many thousands of dwellings built and insulated in the early years of the use of the material have developed serious trouble due to condensation. It was not understood in those days that insulation made it difficult, if not impossible, for a house to "breathe" in the winter. The average uninsulated house maintained its own safe humidity-temperature ratio by the simple method of pushing the dewpoint outside of the walls and the roof. The heat of the dwelling went clear through the structure, and where it met the cold, either in the very outer layer of the roof or wall, or on their surface, its moisture condensed into water droplets. Since the water was outside the building, it did no lasting harm though it was often rather rough on the paint. Of course condensation does occur in uninsulated homes, particularly around windows, but it is by no means as severe a problem as it is in the tightly built, well-insulated, high-humidity homes of today.

In the latter type of dwelling, the meeting-place of warm and cold is moved inside the house, usually somewhere in the outer layer of the insulation or between the insulation and the sheathing. The vapor then collects inside the attic or the wall and the result is plenty of trouble. Wet spots on the ceiling or the walls as the moisture flows down from the cold attic space; falling plaster as an end result; constant and repeated paint failures on the outer walls and gable-ends; and rotting rafters, joists, studs, sheathing, and shingles or siding; these are the only too common and costly results of the over-insulated, under-moisture-proofed home.

The easiest solution, of course, is the inclusion of a good vapor barrier when the house is built. Today in all parts of the country north of what is known as the 35° January isotherm—that line across the southern part of the United States north of which average January temperatures are below 35° (see Figure 1)—vapor barriers should universally be installed in all new dwellings, insulated or not.

A well-known test made by the Forest Products Laboratory and the Housing and Home Finance Agency in 1947 showed that even without attic or other roof ventilation a good vapor barrier could keep moisture conditions in a fill-type insulated attic below the danger point for condensation (see Figure 2). The report, which is full of interest for architects

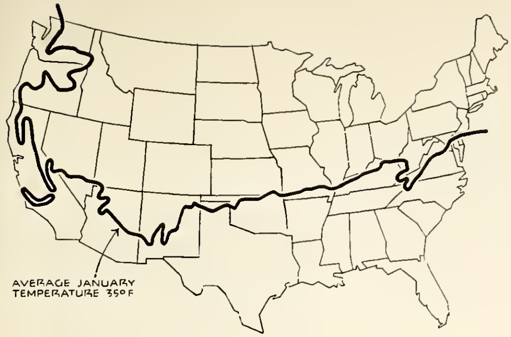
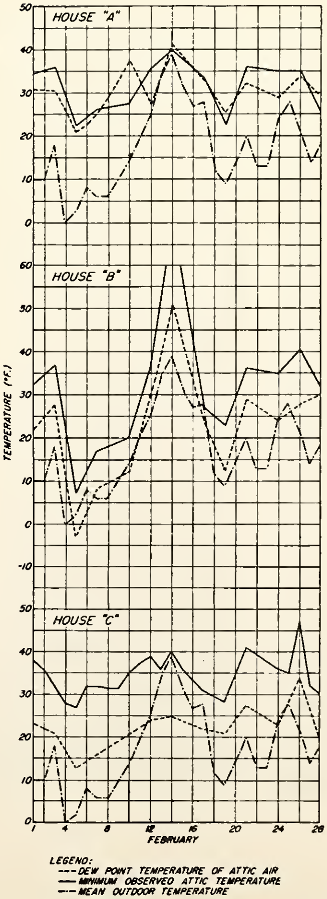


Figure 1 above: to prevent winter condensation problems in areas where the average January temperature is 35 F or lower vapor barriers should be installed in all new houses at the time of construction. (Diagram from Report R1710, U. S. Department of Agriculture, Forest Service, Forest Products Laboratory.)

Figure 2 below: temperature conditions prevailing in attics of three occupied houses during February 1947. All attic floors insulated, that of House B included a vapor barrier. (Chart from *Housing and Home Finance Agency, Technical Bulletin No. 8.*)



practicing in the central and northern parts of the nation, is contained in the Housing and Home Finance Agency Technical Bulletin No. 6, and also in No. 8, which is an especially valuable issue in which several technical reports from previous issues were reprinted.

It cannot be overemphasized that a vapor barrier is an absolute essential in modern homes. A series of laboratory tests made by the Forest Products Laboratory and the University of Wisconsin also in 1947, and summarized in their Report No. R1710, *Remedial Measures for Building Condensation Difficulties,* shows that any barrier which has a vapor transmission coefficient of one grain or less of moisture per hour per square foot will usually (but not always) keep the moisture content of the sheathing in the attic and walls below the danger point for decay. This danger point is stated to be a moisture content of more than 15 percent. The laboratory lists seven types of materials which make adequate vapor barriers, some of them only under average rather than extreme conditions of relative humidity and temperature differentials:

1. Asphalt-saturated and coated papers, 35 to 50 lbs. per sq. ft.
2. Roll roofing, smooth-surfaced, 45 to 65 lbs. per roll of 108 sq. ft.
3. "Some of" the asphalt-laminated papers.
4. "Some, but not all," insulation

Material	Loss in grains per sq. ft. per hour
Foil-surfaced reflective insulation (double faced)	0.066 - 0.136
Roll roofing—smooth surface—40 to 65 pounds per roll of 108 square feet	.068 - .864
Asphalt-impregnated and surface-coated sheathing paper, glossy-surfaced, 35 to 50 pounds per roll of 500 square feet	.158 - .727
Duplex or laminated papers 30-30-30	.487 - 3.530
Duplex or laminated papers 30-60-30	.357 - .512
Duplex papers reinforced	.574 - 4.440
Insulation backup paper	.620 - 10.520
Gypsum lath with aluminum foil backing	.132 - .238
Plaster—wood lath	— 7.90
Plaster—3 coats lead and oil	2.650 - 2.770*
Plaster—3 coats flat wall paint	— 3.080*
Plaster—2 coats aluminum paint	— .831
Plaster on fiberboard	— 14.800
Plaster on gypsum lath	— 13.850
Tarred felt	9.200 - 12.830
Asphalt felts	2.380 - 12.840
Plywood—¼" Douglas-fir, soybean glue, plain	3.080 - 4.620
2 coats asphalt paint	— .308
2 coats aluminum paint	— .930
½" 5-ply Douglas-fir	1.920 - 1.975
¼" 3-ply Douglas-fir, synthetic-resin glue	3.080 - 4.620
½" 5-ply Douglas-fir, synthetic-resin glue	1.975 - 2.420
Insulating lath and sheathing—uncoated	18.50 - 24.65
Insulating sheathing, surface coated	2.19 - 3.05
½" and 1" blanket insulation between coated papers	1.380 - 1.440
4" mineral wool—unprotected	— 20.950

Table 2 left: comparative resistance of various materials to vapor transmission. Many of the materials were tested under actual exposure conditions in laboratory test-house wall panels.

***The test method used was apparently too severe for paint films because the high concentration of moisture had a tendency to destroy the resistance of the film to vapor movement. Wall tests under service conditions show that paint films have a much higher resistance than is shown by the values listed in this table. (Table taken from Report R1710, U. S. Department of Agriculture, Forest Service, Forest Products Laboratory.)**

back-up papers.

5. Reflective insulation of aluminum foil good both sides, and "some of this type with reflective coatings."
6. Aluminum foil-backed rock lath.
7. "Some of" the asphalt-laminated fiberboard lath.

(For a more complete list of materials tested see Table 2.)

Aluminum foil had by far the best rating as a vapor barrier. The vapor transmission factor of foil-surfaced reflective insulation, double-faced, ranged from 0.066 to 0.136 water grains per hour per sq. ft. Roll roofing ranged from 0.068 to 0.864; asphalt-saturated and coated papers from 0.158 to 0.727; other materials ranged from a low of 0.357 for "Duplex or laminated paper, 30-60-30," to 10.520 for one type of insulation back-up paper. Unprotected mineral wool 4" thick had a vapor transmission rate of 20.950, as compared with only 7.90 for a straight plaster and wood lath construction with a "dead air" space between inner and outer surfaces.

The lesson in all this is that architects must assure themselves by impartial tests that the "vapor barriers" sometimes offered on the market as parts of insulating bats or blankets or separately, actually have sufficiently low vapor transmission value. Reflective foil insulations, of course, are themselves nearly perfect vapor barriers when correctly installed.

Vapor barriers must always be placed as near as possible to the inner face of the rafters, the ceiling joists, and the walls, and *always* on the side of the insulation facing into the house not the side facing out. As the FPL report R1710 put it, with vapor seals so placed "the temperature of the barrier will always be above the dewpoint temperature of the room, in which case no condensation will take place on the barrier," or beyond it. In new construction, this means that the vapor barrier should be immediately behind the plaster lath or the drywall surface. Since it is impossible to plaster against a vapor barrier because of the impermeable nature of the material, it must naturally be on the outer face of the lath or on the inner face of the insulation.

Barriers must be as nearly airtight as possible, particularly along the joints between them and the rafters, joists, or studs to which they are fastened, to prevent moisture condensation on these structural members. Many manufacturers recommend that bats or blankets with self-contained vapor barriers be stapled or tacked every two or three inches, care being taken to prevent gaps between the fasteners. Similar precautions should be taken with reflective insulations and with separate vapor barriers. Perhaps the most foolproof method of installation, though more costly, is to fasten the flange of the material to the sides of the structural timbers with ordinary wood lath and two-penny nails, thus assuring a uniform tight closure.

Particular care must also be taken to guarantee a similarly tight joint between rafter or ceiling joist vapor barriers and wall vapor barriers. The best practice is to lap the two widely at the top plate. This is the only safe way to prevent water vapor in the attic from descending into the walls at the eaves and condensing behind the wall vapor barrier.

When loose-fill insulation is used in attic floors it is, of course, essential that a trustworthy vapor barrier of some sort be laid against the topside of the ceiling lath before the insulation is placed. This barrier should be stapled or tacked to the lower sides of the joists to form a tight, self-contained vapor shield.

Furthermore, according to Wilkes and Vianey, in the *Transactions of the American Society of Ventilating and Heating Engineers, Vol. 49, 1943*, it is equally important, this time from the aspect of insulating value rather than from that of moisture proofness, that loose-fill insulation in attic floors should be covered on top with a sheet of vapor-permeable paper. According to these experts, uncovered loose-fill insulation 1" thick has a U-value of 0.312, whereas for a similar thickness covered with a permeable paper it has a U-value of 0.268—a very consequential difference. The Federal Housing Administration's official U-value for this material covered and uncovered is the same—0.202. Suitable papers are inexpensive and easy to lay, and the results in higher heating efficiency in wintertime are noticeable.

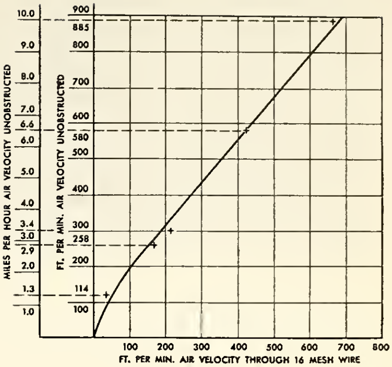


Figure 1 (right): chart showing effect of 16-mesh per inch insect screen in reducing air movement at various wind velocities. (Chart from *Housing and Home Finance Agency Technical Bulletin No. 8.)*

ventilation

A Forest Products Laboratory-Housing and Home Finance Agency test* made in 1947 has shown that a house, with fill-type insulation and a vapor barrier of type unstated, did not actually need ventilation in the winter to prevent moisture condensation. Nevertheless, according to Forest Products Laboratory Report R1710,* "It is to be expected that some vapor will work into the roof space through the barrier or through places not fully protected by a barrier, such as trap doors and around pipes and ducts. The amount is small, and, if uniformly distributed over the roof, would no doubt be unimportant. However, the condensation tends to collect in the coldest parts, and the concentration of moisture may be enough to cause trouble. A combination of vapor barriers and ventilation is obviously the safest procedure."

On the other hand, Wilkes, Hechler, and Queer, in the *Transactions of the American Society of Ventilating and Heating Engineers, Vol. 46, 1940,* state that "In some instances *reflective* insulated structures are vented for summer conditions. However, the vents should be closed for the heating season." Whether or not these men would today state that attic louvers should be closed in winter, in a home provided with reflective insulation, is problematical. If the installation is perfect no ventilation would be needed; but perfection is unattainable. Of course, if a genuinely tight installation has been achieved, closing the louvers in winter will somewhat lower the heat loss in the attic by keeping the attic air more still, thus reducing convection losses. The air temperature may also remain higher, since the radiant heat of the sun will warm up the attic even on the coldest days, undisturbed by the biting air currents coming in through the open louvers.

In any event, ventilation is needed in the roofs of attics of all modern homes, no matter how insulated, if only to add to summer comfort, and also to reduce possible dangers of moisture condensation behind insulations of any type. *Inadequate* ventilation is one of the major causes of moisture troubles in residential roofs. There is an old rule of thumb that the ventilating area in an attic should have a cross-section equal to a basic minimum of half an inch for every square foot of ceiling area in the rooms below. Often this minimum area is provided by louvers, and then the home owner promptly screens the openings. A FPL-HHFA study, which appears in the HHFA Technical Bulletins No. 6 and No. 8, contains data on the reduction of air flow through screened louvers that are quite conclusive. The tests showed that in relatively still air (wind velocity of 1.3 mph) the air velocity through an unscreened louver was 114 fpm (see Figure 1). Through louvers covered with 16-mesh wire cloth it was only 36 fpm. With a wind of about 10 mph, the air velocity through the unscreened louver was 885 fpm, and through the screened louver was 668 fpm. 16-mesh screen actually reduces the clear opening of a louver 30.1 percent—when the screening is kept constantly clean. When it becomes covered with dust, leaves, lint, and other debris, the air flow is, of course, much more greatly reduced.

The consequences of this fact are that there should be a new rule of thumb to establish the amount of attic ventilation needed for winter moisture controls. Louvers that are to be screened should have a total cross-section equal to at least 1 sq. in. per sq. ft. of ceiling area. Everything else being equal, the more ventilation in the attic, the better, both from the aspect of decreasing winter condensation dangers and of increasing summer comfort. The slight added cost of the larger louvers will soon be paid for by the reduction in damage caused by moisture condensation.

There are a number of special design problems in providing natural attic ventilation which must be considered if the ventilating area is to perform its task efficiently. For example, a triangular louver in the peak of a gable is consistently more efficient than a square or round louver some distance below the peak, according to the Forest Products Laboratory. (See Figure 2.) In houses with two or more gables, the necessary ventilating area for the attic

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**Described with regard to vapor barrier on preceding pages.*

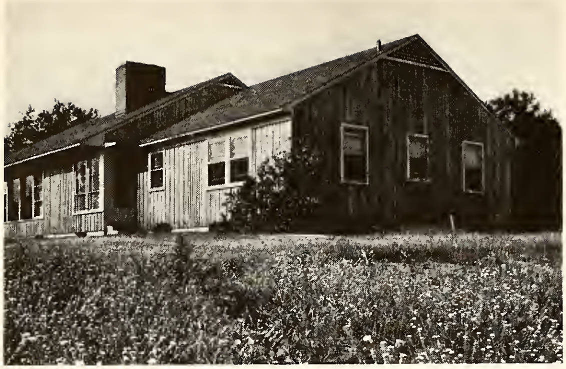

Figure 2 (left): a triangular louver in gable peak is more efficient than square or round louvers located some distance below peak. This home is in Vermont.

Photo: Richard Garrison

should be divided so that equal areas are located in each gable peak.

In houses with hip roofs, screened louvers should always be placed in the eaves, with a total area equal to about 1 sq. in. for every 10 sq. ft. of ceiling area. Globe ventilators, with a total free ventilating area equal to about 1 sq. in. for every 30 sq. ft. of ceiling area should be installed in the ridge to create circulation from eaves to peak. Louvers to be inserted in the faces of hip roofs are available; these hip louvers are also satisfactory, provided, and only provided, that their free area is amply large enough. Most of the standard makes that are available are much too small for the requirements of a moderately sized home.

Whenever the attic insulation is installed between the rafters rather than in the attic floor, the ventilation problem becomes considerably more difficult. Condensation behind such attic rafter insulation is an extremely common cause of trouble, even when a vapor barrier is included. A constant air flow from eave to eave is essential in such instances. Globe ventilators are impractical when the insulation is between the rafters, since one ventilator would be required between each pair of rafters at the peak. Consequently, an eave louver between each pair of rafters on both sides of the roof is the only practical way of providing the necessary ventilation in such installations. No winter closures for eave ventilators should be provided; the circulation of air in this instance is important at all times.

When the insulation is partly in the rafters and partly across collar beams, a combination of eave louvers, gable-peak louvers, and louvers to ventilate the space behind the attic side walls is required.

In flat or shed roofs the problem of ventilation is somewhat the same as it is when insulation is installed between rafters. Usually one solid structural member is used for both ceiling joist and roof support, thus completely sealing off the air spaces between each pair of timbers. Screened eave louvers, roughly 3″ to 4″ in diameter if circular, and ¾″ wide if continuous along the eave, should be provided on both sides of the roof, circular louvers to be provided between each pair of structural timbers.

The problem of the existing home suffering from condensation as a result of unprotected insulation installations is somewhat more difficult to solve. Enlarging the louvers in the attic may take care of part of the problem, but this often is expensive and occasionally, as in homes with brick gables, impractical. A membrane vapor barrier cannot be installed without removing the attic insulation and the inner wall surfaces, and this too, is an expensive proposition. Paint vapor barriers are perhaps the only solution, though rarely entirely effective ones. Under all but the most extreme conditions, however, two coats of aluminum paint on the ceiling, attic finish, and wall surfaces will keep the vapor transmission just under the danger line. Aluminum paint must be used instead of the somewhat more efficient asphalt paint (aluminum paint, two coats, has a vapor transmission factor of 0.950, compared with 0.308 for asphalt paint) since the asphalt paint cannot be covered by any interior finish, either paint or wallpaper, without eventually showing through. If two coats of aluminum paint are covered with two more coats of glossy lead and oil paint as a finish, however, the danger of too much moisture condensation beyond the paint barrier is rather remote, and no further condensation troubles should be expected except in the most aggravated climatic conditions.

A well-insulated, well ventilated roof, with an adequate vapor barrier, will definitely prevent unnecessary heat loss and eliminate the danger of excessive moisture condensation in the winter, provided the installation and construction work is well done, and the amounts and quality of material and area of ventilation are ample for the worst climatic conditions to be expected.

summer ventilation

Ventilation and insulation for summer comfort may change the design of a roof considerably, if the most effective results are to be obtained. For example, the larger the louvers, the more effective the natural ventilation. However, there is a point beyond which too-large louvers will actually cause excessive winter heat loss; consequently, the changes for summer comfort should not necessarily be in the materials and louvers provided for adequate winter protection, but rather in the addition of new elements.

For example, if a roof is designed to be insulated with a convective material, the addition of a single layer of reflective foil, good both sides, between the roof sheathing and the insulation, will reduce downward heat flow in the summer to a remarkable extent. A minimum of 1″ of free air space between the roof sheathing and the foil, and the foil and the insulation, should be provided so that the full insulating value

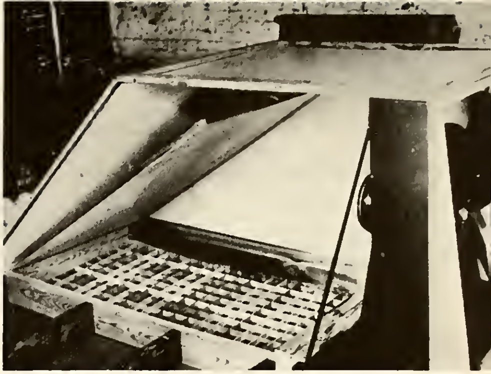

Figure 3 (right): cut-a-way view of an attic fan installation. Trap door closes over wooden grille when plenum fan is not in operation.
Photo: courtesy Texas Engineering Experiment Station.

of a motionless air space may be obtained. This value is stated by Dill, of the Bureau of Standards, to be highest when the air space is approximately ⅞" wide.

In homes located in really hot parts of the country, or regions where both excessive summer heat and winter cold exist, even this precaution will not achieve real summer comfort. And since a cool home in the summer is not only pleasant but often a considerable aid to good health, architects working in regions where summer temperatures frequently go over 80F should ask their clients to consider the long-term values of other methods of reducing heat inside the house.

There are three major ways to achieve greater summer coolness, the most important of which is *forced* ventilation. The others, which are light roof coverings and moistened roof surfaces, will be discussed later.

The most efficient, and also the most expensive, type of forced attic ventilation is the plenum-type attic fan installation, which draws air up from the rooms below through a ceiling grill, and forces it out through attic louvers, (see Figure 3). In Texas, where it gets really hot in the summer, the Engineering Experiment Station of the Agricultural and Mechanical College at College Station, Texas, has worked out a useful handbook on the types, sizes, and installation of attic fans, with emphasis on the plenum type. This bulletin is called *The Installation and Use of Attic Fans*, and is written by Research Associate W. H. Badgett. It presents a number of important suggestions on ceiling grill construction and location, required grill sizes for various sizes of homes and of fans, and the construction of the plenum box for the fan. Size of fan, naturally, depends on the cubage of the area to be ventilated, the rate of air exchange desired, and the power of the fan being purchased. Rate of air exchange recommended for various parts of the country has been established in the Attic Ventilation Code of the Propeller Fan Manufacturers' Association, Detroit, Michigan. This Code states that in the New England states, New York, Pennsylvania, Michigan, Wisconsin, Montana, Washington, and parts of New Jersey, Virginia, West Virginia, Ohio, Indiana, Illinois, Minnesota, Wyoming, North Dakota, Idaho, Oregon, and California, the attic fans should be large enough to change the air once every 1½ minutes. In all other parts of the country, they should be large enough to change the air once every minute.

The actual reduction in temperature resulting from the use of a plenum-type attic fan has not been determined, as far as this author knows. It may be rather small. However, the well-known cooling effect of air in motion across the skin achieves a much higher degree of physical comfort than the temperature differential might indicate, since it encourages evaporation of perspiration.

Other types of forced ventilation in the attic are fans set in pre-existing louvers or windows, or in louvers cut especially to fit them. Some fans are provided with metal louvers ready to install. Unless the attic is extremely tight, and a grill or open attic door is provided so that the air from the rooms below can be pulled up by the fan, the most this type of installation will do is keep the attic itself cool. In moderate climates non-plenum attic fans will add considerably to the comfort of the home, but wherever uncomfortably hot summers are experienced, the plenum type is to be preferred.

There are a number of important technical factors which must be borne in mind when preparing for the installation of attic fans. For the plenum type the ceiling grill must be located centrally so that it will pull air more or less equally from all the rooms that are to be ventilated, and large enough to fit the air demands of the fan being installed. Fans in general should be chosen carefully, with due attention to optimum size, durability, silence, cost of operation, and amount of required maintenance. Most large fan manufacturers have design departments which can help architects arrive at satisfactory formulas for various types and sizes of homes, and also to advise on the necessary louver sizes for efficient air exhaust.

white roofs

The cooling effect of a glossy white roof covering is worth note by architects looking for novel methods of weather conditioning residences for summer comfort. Building Materials and Structures Report BMS-64, *Solar Heating of Various Surfaces*, published by the Bureau of Standards in 1941, revealed some rather startling facts about the relative heat-reflecting efficiencies of different roof colors and textures. Tests were made on 17 materials or surfaces, exposed to midsummer Washington heat on a panel held at inclinations of 90°, 60°, 45°, and 30° from the horizontal, over a period of five days (see Figure 4). A section of the surface covered with lampblack was used as a control; it showed daily mean rises in temperature ranging from 20.9° when

Date (1939)	Aug. 2	Aug. 3	Aug. 1	July 31	Aug. 7
Panel inclination from horizontal	90°	90°	60°	45°	30°
	°F	°F	°F	°F	°F
Black (lampblack)	20.9	21.0	37.4	46.3	48.5
Galvanized iron	16.1	15.3	28.1	32.0	37.7
Roofing shingle, aluminum	19.4	20.2	34.1	40.7	41.6
Roofing shingle, green	19.5	20.7	33.3	41.3	43.4
Roofing shingle, red	21.5	23.1	37.2	44.8	46.0
Aluminum foil	9.8	8.3	15.0	17.3	19.7
White road-marking paint	12.3	12.1	19.7	22.9	24.7
Aluminum paint	14.6	14.5	24.4	29.0	29.3
Glossy white paint	8.9	7.9	12.1	13.0	15.5
Flat white paint	9.1	8.3	13.2	15.6	17.2
Ivory paint	10.2	9.3	14.9	16.8	19.2
Canary-yellow paint	10.9	10.4	16.7	19.2	21.6
Pearl-gray paint	13.3	13.7	20.3	24.3	25.6
Silver-gray paint	13.9	14.2	20.3	24.6	26.3
Light lead paint	15.1	15.2	22.9	27.4	29.7
Slate paint	16.8	17.1	26.7	32.4	35.4
Medium-green paint (trim color)	20.4	20.5	35.3	42.7	46.3

Figure 4 (left): daily mean rise in temperature in degrees Fahrenheit of test panels exposed to the sun. (Table from *Building Materials and Structures Report BMS-64,* Bureau of Standards, U. S. Department of Commerce.)

in a vertical position to 48.5° when 30° off horizontal. Glossy white paint, on the other hand, showed mean temperature rises of only 8.9° at vertical to 15.5° at 30° from horizontal. This was one case in which a material was somewhat better than aluminum. Aluminum foil's temperature rise was from 9.8° to 19.7°. Aluminum roofing shingles showed a temperature rise from 19.4° to 41.6°—only a little better than lampblack. A standard roll roofing with crushed green slate as a surface, such as is commonly used on homes in the middle price range, had temperature rises from 19.5° to 43.4°.

Every degree of temperature a color or material rose in this test was a degree on the immediate *underside* of the reflecting surface: i.e., a degree which had penetrated the surface and, had it been on an actual roof, would have gone straight into the roof sheathing, the attic insulation, or the attic air if there was no insulation.

It has, of course, long been known that white is a remarkable heat reflector. Men wear light clothes in the summer because they are cooler; they reflect more heat than dark cloth. However, the application of this theory to home roofs is something that very few architects and home owners have thought of.

The costs of such a roof, whether tile or porcelain enamel, are, of course, somewhat higher than those made of more common materials, but the added comfort factor, which is made apparent by the Bureau of Standards figures, might in many installations make the difference worthwhile. The white roof is exceptionally handsome, though some customers may object to it on the ground that it is "different." It seems not to suffer too much from dirt or grime in the atmosphere, though porcelain enamel manufacturers advise periodic washing, which may be a maintenance problem militating against use of the idea.

Of course, whenever materials like tile or porcelain enamel are used, they create what is in effect a moisture barrier on the wrong side of the roof, just as do aluminum shingles, and all asphalt-based or asbestos shingles, and all types of metal roofing. Unless thoroughly adequate ventilation and an impervious vapor barrier is provided, moisture condensation will very soon cause trouble. Actually, the only roofing surface which does not act as a more or less efficient vapor barrier on the wrong side of the roof is one made of wood shingles. These are fairly permeable to fine water vapor, while at the same time being proof against actual rain water or melted snow.

water-cooled roofs

The final technique that the architect has at his disposal for increasing summer comfort in residences, outside of air refrigerating units themselves, is the water-cooled roof. It is likely that this method will prove to be of more value in summer conditioning existing homes than in the design of new dwellings, since the latter can be provided with all the necessary cooling elements—insulation, vapor barriers, and forced-air ventilation, as well as the white roof if desired—that would be needed even in the hottest climates found in this country. A water-cooled roof takes fairly constant maintenance, and consequently is not preferable to other methods which are more or less automatic.

In existing homes, however, water-cooling often may be the least expensive and most efficient method of increasing summer comfort. There are three methods of providing this type of summer protection: the water pool, which is suitable only to absolutely flat roofs; the sprinkler installation, which can be used on both flat and pitched roofs; and the trickle type, which is of value only on roofs with a considerable pitch.

The construction of most flat-roofed houses is amply strong enough to stand the added weight of the 6" pool of water, which is most efficient for summer cooling. Whether the roof is waterproof enough is something else again. Certainly no roof which has been exposed to the elements for a number of years can safely be used as a pool base unless the whole surface is carefully gone over, and new layers of pitch and tar paper to make an absolutely waterproof new surface. If the roof has a 6" watertight coping to hold the pool, there is no reason why it cannot serve well as a pool base.

According to Houghten, Olson, and Gutberlet in the *Transactions of the American Society of Ventilating and Heating Engineers, Vol. 46, 1940,* 6" of water on top of a built-up roof consisting of 2" pine boards, five plies of felt, three of which were set in pitch, and double-poured pitch and slag roofing, permitted maximum heat flow on a hot summer day of 2.8 Btu. per hr. per sq. ft., as compared with 11 Btu. per hr. per sq. ft. for dry surface. This reduction in heat transmission unquestionably means much cooler conditions inside the house. A similar roof section covered with a 1" deep pool had maximum heat flow of 4.7 Btu. per

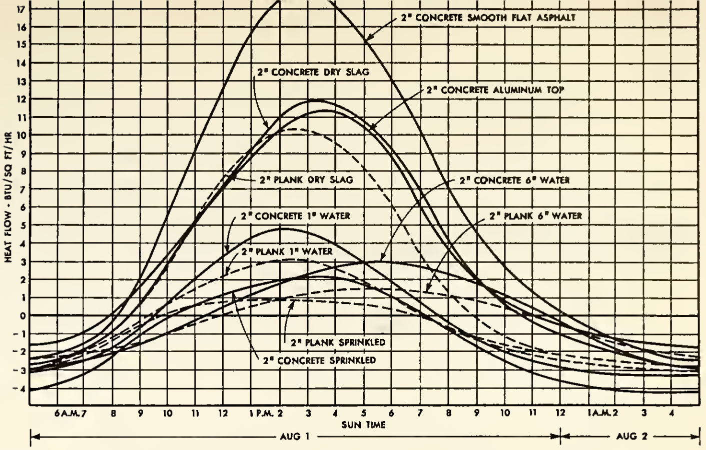

Figure 5 (right): relation between time and heat flow through inside surfaces of several horizontal roofs; corrected to design day, August 1. (Chart from *Transactions A.S.H.V.E., Vol. 46, 1940.*)

hr. per sq. ft., about 60 percent higher than the 6" pool.

The disadvantages of a water pool are sometimes marked. It makes an excellent breeding place for both algae and mosquitoes, unless preventive chemicals are added. Furthermore, all the pollutions of the atmosphere—dust, pollen, soot, oil vapor, leaves, and so on—will naturally settle on the pool's surface, thus dulling it and reducing its reflectivity, in essence turning it into a heat trap. Pools usually have to be drained and fresh water put in every week or so, to renew the brightness of the surface. This means an added maintenance problem for the home owner.

While the 6" pool had a maximum heat transfer factor of 2.8 Btu. in the A.S.V.H.E. tests just mentioned, the same type of roof construction sprinkled with just enough water to keep it damp had a heat transmission rate of only 2.1 Btu. Inasmuch as the installation of a roof sprinkler system is moderate in cost (estimated at from $100 to $400, depending on the size and complexity of the roof), and as such a system can be used both on flat and pitched roofs, it seems to be a preferable method of cooling residential roof surfaces. Since it relies on a high rate of evaporation rather than on reflectivity for its cooling effect, there is no need for any great quantity of water; just enough to keep the roof surface damp. The dusts and soots of the atmosphere will not affect the evaporation rate, either, so that the cooling effect will remain about as efficient in a location with a polluted atmosphere as in one in which the air is relatively clean.

The April Showers Company, Washington, D. C., and the Water Cooling Corporation, New York, N. Y., both have had considerable experience in designing water sprinkling systems for roofs, the latter primarily for industrial installations. The sprinkler systems, like the pools, can be used on concrete roofs as well as on wood base roofs; the cooling effect on concrete is only slightly inferior to that on wood, as the A.S.V.H.E. tests show. One of the peculiarities of the roof sprinkler system is that it works better when the roof is poorly insulated than when it is well insulated. This may make the system more desirable in southern climates, where winter insulation is unnecessary, than in the north where it is essential.

Sprinkler systems are controlled by thermostats which turn the water off and on as the temperature of the roof surface falls and rises. This thermostatic control assures automatic operation, and a very low water consumption, considering the comfort achieved. There are some maintenance problems in the sprinkler system, of course, as in any mechanical equipment, but they are minor and should not be important in the over-all consideration of the usefulness of water sprinkling as a cooling method.

Probably the cheapest technique for roof cooling is the trickle method, usable only in pitched roofs. This involves, simply, placing a perforated pipe along the ridge of the roof and permitting a flow of water through the perforations just heavy enough to keep the roof damp. The major difficulties with this system are that it sometimes means too much water on one end of the roof and not enough on the opposite end; that it cannot be effectively controlled by a thermostat, since the temperature changes will be unequal; and that, since effective cooling depends on dampness of the complete surface, it usually results in some wasted water. In order to keep the roof damp at the eave, more water than is needed at the peak must be used, with a consequent runoff. Moreover, dirt on the roof will make the system less efficient by causing the water to form into rivulets, thus cooling only parts of the surface. However, in rural areas where water supply is abundant and cheap, the atmosphere relatively clean, and installation costs a decisive factor, the trickle method of cooling may be a useful idea.

It is obvious that what is generally needed to control the external environment of northern New York State, where winter temperatures may go down to 30° below zero and summer temperatures often up to 90° or 100°, is quite different from what is needed in Arizona, where the temperature range is from 50° to 120°. Architects will have to plan for year-round weather conditioning entirely in terms of the weather they want to condition, the home that is to be conditioned, and the home owner's tastes and financial abilities.

The fact is, however, that despite the still-large gaps in the research data on various aspects of the problem, climate can be controlled practically everywhere in the continental United States, so that homes can be relatively comfortable at all times of the year, and genuinely economical to heat whenever conditions of cold are encountered. This marks quite a considerable advance over the days not so long past when the average home was designed for durability, strength, and appearance, and the weather was allowed to do everything it could to make the house uncomfortable all the year round.

FOUNDATIONS

All loads—roof loads, floor loads, and column loads—must be transferred to supporting rock or soil. Depending upon the design of the superstructure and the allowable soil pressure, the particular type of footing will be considered most appropriate. Commonly used are spread footings, combined footings, mats, piles, and caissons. Occasionally, a column or pier can be brought to bear directly on bed rock without undue length or change of size at the base, but most often some sort of footing must be designed so that the soil can resist the load asked of it. Generally speaking, it would be quite in error to assume that pile foundations could be competitive with spread footings as ordinarily designed; however, a method of installing displacement caissons now gaining popularity in this country offers this possibility. This method can be described as a process of injecting spread footings into the soil to obtain the advantages of depth, the elimination of excavation, and the establishment of a highly compressive shell of soil surrounding the footing. Known commercially as Franki Foundations (originated over 40 years ago in Belgium but only recently introduced to the United States) the component parts of the required equipment for placing these caissons comprise a rig, a heavy-gage tube of high-tensile-alloy steel, and a ram. In operation, the rig moves itself (by a hydraulic walking mechanism) so that the geometric center of the steel casing is placed over the stake indicating the surveyed location of the caisson. Dry concrete is then dropped to the bottom of the tube and is tamped by the ram to form a driving plug. (As the ram's fall is actuated by gravity and as the tube is pulled into the ground rather than being driven from the top, it is virtually impossible for the tube to take any course other than a straight one.) After the casing has been driven to a resisting soil stratum, small quantities of dry concrete are dropped into the annular space between the ram and the casing and, by additional ramming, a spherical bulb of concrete is formed—the required volume being dependent on the density and other characteristics of the soil. Experiment has shown that the soil is highly compacted for a distance of one foot surrounding the bulb. At successive intervals, the tubing is withdrawn leaving a highly compacted concrete in the shaft measuring 21 in. to 24 in. in diameter. Individual caissons have stood up under test loads of over 500 tons.

Footings on Typical Sandy and Clayey Soils

BY RALPH B. PECK, WALTER E. HANSON AND THOMAS H. THORNBURN*

The construction of foundations is one of the oldest arts of mankind and, until the last decade, one of the least influenced by scientific methods. The last few years, however, have brought about a major revolution. The impact of science, now that it has finally made itself felt, has been almost overwhelming. The literature concerning foundations has tended to become highly technical, even to the point of discouraging the practicing architect or engineer. Fortunately, there has recently been a serious effort to evaluate the contributions of science and to formulate practical procedures embodying the benefits to the scientific development. Soil mechanics is the name given to that branch of science applicable to foundation engineering.

Probably the most important single decision to be made in connection with the design of any foundation is whether the structure should be supported at a shallow depth on footings or a raft, or at greater depth on piles or piers. If this decision is correctly and intelligently made, it is very unlikely that any disastrous or even undesirable consequences will develop. But if this decision is incorrectly made, little can thereafter be done to produce an adequate design. If a structure is placed upon a shallow foundation which should have been a deep one, no refinements in connection with the design of the footings themselves, their layout, or the distribution of loads among them can prevent settlements that might have their origin in deep-seated layers. If the structure is established on piles when footing foundations would have been adequate, no refinements in the choice of the type of pile or in the selection of the load per pile can mitigate the inherent lack of economy of the design. There are, of course, borderline cases for which foundations of either type are acceptable.

The logical way to choose between a shallow and a deep foundation is to predict the behavior of the structure assuming it to be established upon a shallow foundation. If footings of reasonable size which exert reasonable pressures on the subsurface materials can successfully be used, they are generally the proper choice. If the forecast of the behavior of the structure indicates that the settlement will be too great, or that the soil will be seriously overstressed, even when large footings or rafts are used, then deep foundations are indicated.

Experience has indicated that shallow foundations may exhibit two quite different types of unsatisfactory performance. The soil beneath the footings or rafts may be overloaded to the point that it actually fails by slipping, one part on another. Such a rupture of the soil beneath a foundation is known as a bearing-capacity failure. The structure resting on a soil that fails in this manner either experiences sudden and disastrous settlements, or overturns completely. The second type of unsatisfactory performance may not be so disastrous, but it is far more prevalent and in the long run accounts for far greater economic losses. This type is the excessive differential settlement of a structure due to the compression of the soil beneath the various parts of the foundation. In this case, the stresses in the soil are not large enough to cause rupture; indeed, they may be quite mild compared to the ultimate bearing capacity of the ground. Nevertheless, they may be sufficient to cause appreciable changes in the volume of the soil beneath the footings. If these changes are not equal beneath all the footings, important differential settlements may develop and cause structural or architectural damage to the superstructure.

It has been found that the two types of failure are virtually independent of each other and that separate investigations may be conducted to determine the relative safety. Soil mechanics also indicate that there are basic differences in the physical properties and the stress-strain characteristics that determine the behavior of sandy soils and clayey soils. Therefore, each type of failure must be studied in connection with each of these two major classes of foundation soils.

Before discussing methods of predicting the ultimate bearing capacity of footings on these two types of materials, it is necessary to say a word about the exploration and the determination of the physical properties of the soil deposits upon which the structures are to be erected.

One of the major contributions of science to foundation engineering has been the realization that the typical properties of soils must be described in quantitative or semiquantitative terms, rather than in terms of words whose meaning often may be misunderstood. In most instances, the necessary quantitative information can be obtained at relatively low cost, although for a few problems refined and somewhat expensive procedures may be necessary.

Test borings are still the most common method for exploring the subsoil and are generally preferable to test pits or other types of exploration. It is of little impor-

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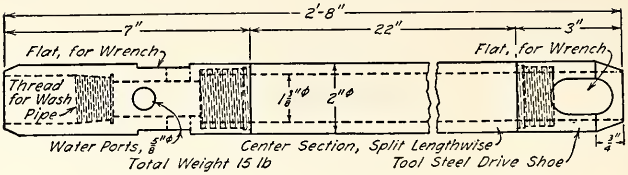
*Research Professors of Soil Mechanics, University of Illinois, College of Engineering, Urbana, Ill.

Much of this article, including most of the illustrations, condensed from the authors' recent book, Foundation Engineering, *published by John Wiley & Sons, Inc. For more complete treatment, and for discussions of more difficult conditions, the reader is referred to this volume.*

Figure 1—split-spoon sampler used in standard penetration test.



Penetration Resistance and Soil Properties on Basis of the Standard Penetration Test

Sands (Fairly reliable)		Clays (Rather unreliable)	
No. of blows per ft, N	Relative density	No. of blows per ft, N	Consistency
		Below 2	Very soft
0–4	Very loose	2–4	Soft
4–10	Loose	4–8	Medium
10–30	Medium	8–15	Stiff
30–50	Dense	15–30	Very stiff
Over 50	Very dense	Over 30	Hard

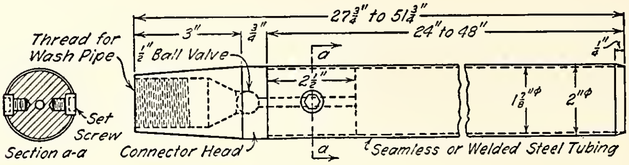


Figure 2—two-in. tube sampler.

tance whether the hole is made in the ground by wash boring, rotary drilling, or hand augering. The important considerations are that truly representative samples should be obtained for inspection and description, and that numerical values, at least approximately indicative of the physical properties of the materials, should be determined.

During recent years in the United States and in many other parts of the world, it has become the custom to make exploratory borings of 2½ to 3 in. diameter. Samples are obtained by inserting into the hole a standard sampling spoon *(Figure 1)* which has an outside diameter of 2 in. and an inside diameter of 1⅜ in. A weight of 140 lb is dropped through a distance of 30 in. on the upper end of the rods, and the number of blows required to advance the sampling spoon 1 ft into the ground is recorded. This number of blows, N, is referred to as the standard penetration resistance. Samples from the sampling spoon, although appreciably disturbed, usually contain all the materials representative of the undisturbed soil.

N-values indicate, in a general way, whether the sand is in a loose or dense state, or whether a clay is soft, medium, or hard. In connection with sands, in particular, a knowledge of the looseness or denseness is of the greatest practical importance; and the N-value constitutes the basis for the procedures of forecasting behavior that will be described subsequently. The meaning of the various ranges of N-values in terms of verbal descriptions of the relative density or consistency of sandy or clayey soils is indicated *(see table)*.

Standard penetration tests should be made in connection with the preliminary exploration at the site of almost any project. In sands, the penetration tests should be made at intervals of 2½ to 5 ft in the vertical direction for a distance of 10 to 20 ft below the anticipated footing level and at 5 ft intervals thereafter, until it is certain that all soft or loose layers that would have an influence on the design of the foundation have been penetrated. At least one boring, possibly two or more, should be carried to a considerable depth, often as much as 50 or 100 ft for all but the most insignificant structures, to make sure that no soft materials, particularly soft silts or clays, are present at considerable depths below the foundation level. Such layers, as will be seen later, may be sources of difficulty. Moreover, if piles or piers should be found necessary, the deep borings will be necessary for estimating the length of the piles or the depth of the piers.

If the soil encountered by the sampling spoon is a soft or medium clay, the standard penetration resistance may not be a sufficiently accurate measure of the consistency for use in design. A considerably better measure is the unconfined compressive strength of the clay. This value is determined by means of a simple compression test such as that made on a concrete test cylinder: it is the axial stress on the cross section of a cylindrical sample at the time the sample fails, or at the time the sample has shortened by 20 percent of its original length if outright failure does not occur. Instead of the standard sampler, a thin-walled sampler is often used. This device is commonly known as a Shelby-tube sampler *(Figure 2)*. The samples obtained in thin-walled tubes are relatively undisturbed and their strengths can usually be considered a satisfactory representation of the strengths of the soil in the ground. No special boring equipment is required to obtain Shelby-tube samples, because the tube has the same external diameter as the standard split spoon and may be used interchangeably with it whenever soft clayey soils are noticed by the boring foreman.

The water content, liquid limit (determined in the laboratory), and plastic limit are useful in estimating the compressibility of the clays in order to make a computation of the settlement due to the weight of the proposed structure.

The equipment for performing the unconfined compressive-strength test is relatively simple and the determination of the moisture content requires no special equipment. The apparatus and procedures for determining the liquid and plastic limit tests are ASTM standards.

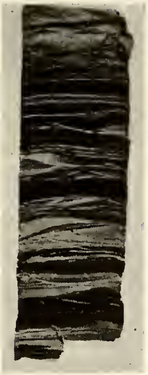


Figure 5

Regardless of the method of drilling or sampling, the position of the ground-water level should be determined as accurately as possible, especially if the subsoil contains any permeable strata.

The cost of Shelby-tube sampling is somewhat greater than the cost of spoon sampling. In addition, the cost of the necessary laboratory tests must be added to the cost of the exploration. As a rule, standard penetration-test borings cost from $3.00 to $6.00 per lineal foot, depending on the consistency of the material, whereas the taking and testing of continuous 2-in. Shelby-tube samples ordinarily costs between $7.00 and $12.00 per ft.

When test borings have been made at a site and the results of the standard penetration test or the laboratory tests are available, the engineer must first summarize the results, usually in graphical form, in such a manner as to give him a clear concept of the engineering characteristics of the subsoil. The most suitable method of summarizing and plotting depends upon the character of the structure, the geology of the site, and the nature of the exploratory program. A few examples are probably the best indicators of the methods that can be used. The results of explorations made by means of the standard penetration test in deposits of sand or sand in combination with silt and organic matter are shown *(Figures 3 and 4)*.

The preceding examples indicate the type

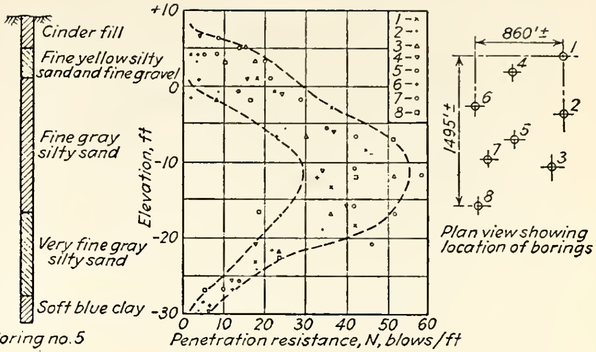


Figure 3—a typical boring log, the results of standard penetration tests in eight borings, and a plan showing the locations of the borings on a building site in northern Indiana near the south end of Lake Michigan. The penetration resistance profile shows very clearly that the density of the sand deposit from about El. -10 ft to El. -15 ft is considerably greater than it is at elevations either above or below. The materials at this site are probably a combination of beach sands and dune sands. The various borings show a better agreement among the values of penetration resistance at various depths than would ordinarily be expected if the sands were alluvial in nature.

Figure 4—a geological cross-section including penetration resistance values of a deposit near the mouth of the Milwaukee River in Wisconsin. The materials represent a composite alluvial and shore deposit. Its complexity is partly the result of variations in the level of Lake Michigan during the glacial period. The penetration resistance profile shows very definitely that the deposit consists of predominantly loose and soft materials to a depth of at least 40 ft. There are several large zones of peat and soft organic silts which are highly compressible and, therefore, unsuitable foundation materials. This cross section leaves little doubt that any suitable foundation must extend through all the compressible materials to the firm base at a depth of about 50 ft.

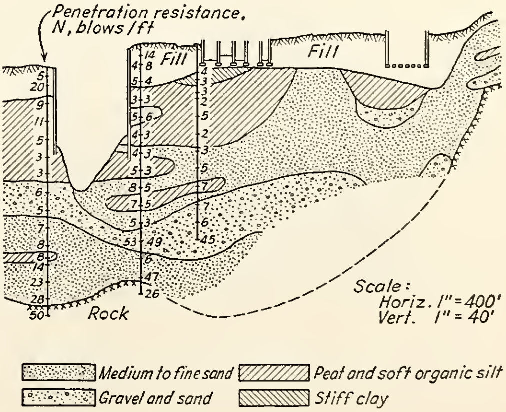
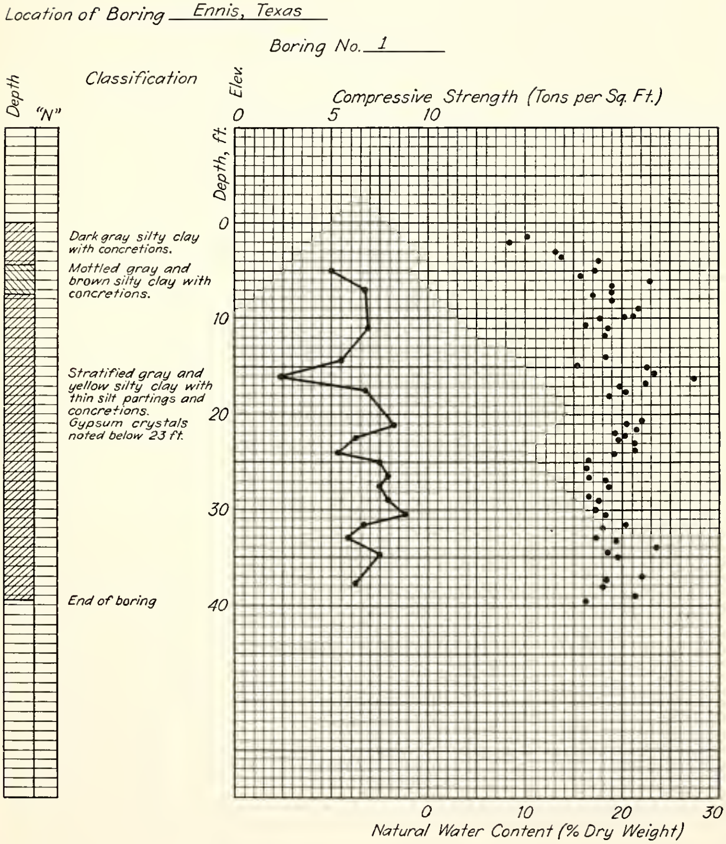


Figure 6—a boring log showing the water content and unconfined compressive strength profiles for a silty clay soil from the Coastal Plain region about 40 miles south of Dallas, Texas. The figure shows the material to have the characteristics of a very stiff clay below a depth of 5 ft. The minimum unconfined compressive strength value is about 2½ tons/sq ft. However, throughout most of the depth of the boring, extending nearly to 40 ft, the strength ranges between 5 and 8 tons/sq ft. The moisture content varies between 15 and 25 percent. Although the strength of the material is certainly great enough to support nearly any structure on footing foundations, local experience has shown that the greatest engineering problems are the result of changes in moisture content in the soil. In this semiarid region the moisture content of the upper portion of the soil increases considerably during certain times of the year, whereupon the soil tends to expand and to exert very high swelling pressures. The movements and pressures often disrupt structures resting on the clay. Thus, this example may be considered an illustration of the importance of knowing more about the behavior of foundations in a locality than ordinary borings and routine tests can disclose.



of information that can be obtained from standard penetration tests alone. The character of sampling that can be done by means of commercial 2-in. Shelby-tube samplers is shown in a photograph *(Figure 5)* of a sample taken from the bed of glacial Lake Agassiz, near Fargo, North Dakota. The intricate nature of the banding of the subsoil contains dangerously loose or weak layers, and to indicate to the engineer the various levels at which it would be reasonable to consider the establishment of foundations.

The mere presentation of the results of a simple program of borings and soil tests in forms such as those shown *(Figures 3 to 6)* is often sufficient to point out where the subsoil contains the establishment of foundations. Thus, the quantitative subsurface exploration, even without further analytical study, serves an extremely useful purpose and may prevent serious errors.

If footings would be underlaid directly by sand, an investigation should be made to determine the maximum soil pressure that could be used without excessive differential settlement, and a separate investigation carried out to determine the maximum soil pressure corresponding to adequate safety against a bearing-capacity failure. Both these investigations can be made on the basis of the N-values determined from the standard penetration test.

The first step is to make a rough estimate of the size of the largest footing in the structure. This can be done by assuming a conservative soil pressure and dividing it into the maximum column load. The average N-value for each of the borings on the site is then determined for a depth equal to the width of the assumed largest footing. The smallest of these average N-values is regarded as the basis for design because sandy subsoils have a generally erratic structure and it must be assumed that the poorest conditions disclosed by any one boring might occur beneath one of the largest footings.

After the average N-value has been determined, the chart *(Figure 7)* may be utilized to determine the soil pressure that will lead to reasonable settlement of the footing. This chart should be entered with a width equal to that assumed for the largest footing in the structure. The soil pressure so determined, or corrected if the initial assumption of the width of the footing was appreciably in error, should not lead to a settlement of that footing greater than 1 in. Such a settlement is generally considered tolerable in almost any structure of modern design. The soil pressure determined for the largest footing is used for proportioning the areas of all the other footings beneath the structure.

After the soil pressure for settlement has been determined, the two charts *(Figure 8)* are entered to determine the soil pressure at which the factor of safety against a bearing-capacity failure will be equal to three. The first of the two diagrams gives that portion of the safe soil pressure due to the weight and strength of the soil beneath the level of the footing. The second part gives that portion of the safe soil pressure due to the weight of any surchange that exists around the footing above the level of its base. The sum of these two soil pressures is the safe pressure that will provide an adequate margin of safety against a bearing-capacity failure. This value should be determined for each footing.

If the soil pressure corresponding to a 1 in. settlement is less than that required to provide a factor of safety of three against a bearing-capacity failure, then the soil pressure is governed by settlement. On the other hand, if for any footing the allowable pressure for settlement is greater than that permitted for bearing capacity, then the value for bearing capacity should be used as the basis for design of that footing. Usually only narrow shallow footings are governed by considerations of bearing capacity rather than settlements.

The soil pressures determined by these procedures are based on the assumption that the ground-water table is located at a greater depth below the base of the footing than the width of the footing. If the ground water is higher than this depth, a reduction in the allowable pressure must be made. If the water table is at the elevation of the base of the footing, the values given by the settlement chart *(Figure 7)* should be divided by 2. If the water table is at some depth intermediate between the base level and the width of the footing below base level, a linear interpolation can be utilized to obtain the correction factor. In connection with bearing-capacity computation, a similar correction is made *(for Figure 8a)*. Moreover, if the water table is above the base level of the footing but be-

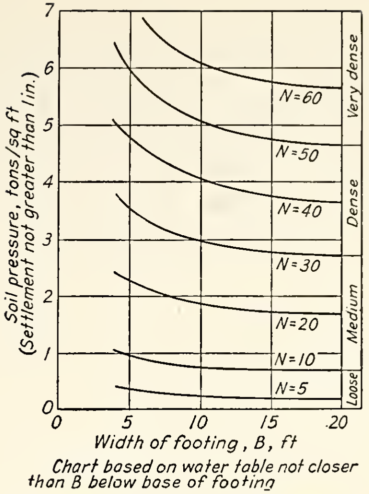
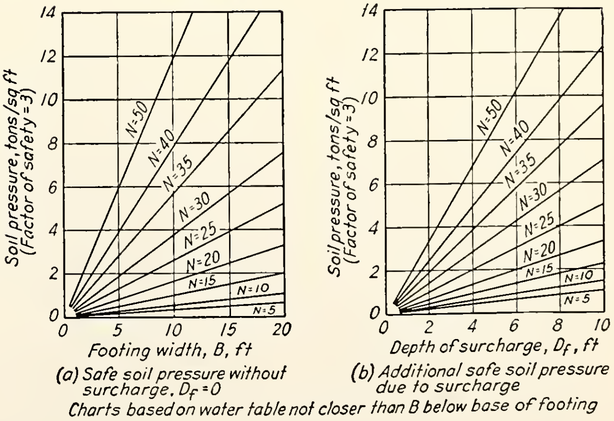


Figure 7—soil pressure corresponding to 1-in. settlement of footings on sand.

Figure 8—safe soil pressures beneath footings on sand as determined by bearing capacity.



(a) Safe soil pressure without surcharge, $D_f = 0$

(b) Additional safe soil pressure due to surcharge

Charts based on water table not closer than B below base of footing

Footing Design. Required Areas.

Borings carried to a depth of 50' within the building area give the following information:

(1) Medium to coarse sand from ground surface to bottom of hole.
(2) Water table at a depth of 34 ft.
(3) Minimum average N value from base of footings to a depth of 20' = 35 blows/ft.

No soft stratum exists below the sand.

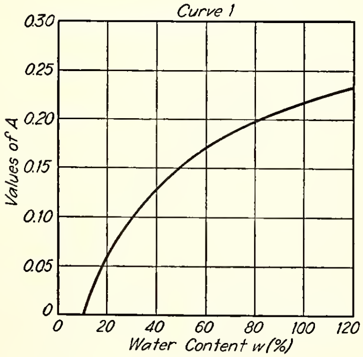
Interior: 249^T
@ say 3.5 = 71 sq ft
Try 8'-6"x8'-6": A = 72.3 sq ft Assume depth = 2'-6"
Column load = 249^T
$\div 72.3 = 3.45\ {}^T/\text{sq ft}$
Additional load:
$$\left.\begin{array}{l}\text{Floor slab} = 0.5 \times \frac{0.15}{2}\\ \text{Footing} = 2.5 \times \frac{0.15}{2}\end{array}\right\}\ 0.22$$
$\overline{3.67}$
Surcharge load:
$$\left.\begin{array}{l}\text{Floor slab} = 0.5 \times \frac{0.15}{2}\\ \text{Soil} = 2.5 \times \frac{0.10}{2}\end{array}\right\}\ 0.16$$
$\underline{\overline{3.51\ {}^T/\text{sq ft}}}$
From Fig. 7 allow $\underline{3.6\ {}^T/\text{sq ft}}$
From Fig. 8 allow 4.8 + 2.9* = $\underline{7.7\ {}^T/\text{sq ft}}$
Use 8'-6"x8'-6" for interior footings

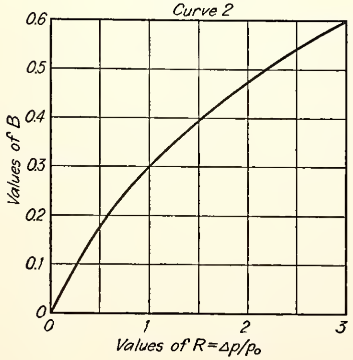
Footing Design. Required Areas. Effect of Water Table

The following computations illustrate the effect of the water table on footing areas. The water table is located approximately 5 ft below the base of the footings. Hence, a decrease of 25 per cent must be made in the allowable soil pressures given in Fig. 7 and Fig. 8.

Interior: 249^T
@ say 3.4 x 0.75 = 98 sq ft
Try 10'-0"x10'-0": A = 100 sq ft Assume depth = 2'-6"
Column load = 249^T
$\div 100 = 2.49\ {}^T/\text{sq ft}$
$$\left.\begin{array}{l}\text{Additional load}\\ \text{minus surcharge}\end{array}\right\}\ 2.5\left(\frac{0.15-0.10}{2}\right) = \underline{0.06}$$
$\underline{2.55\ {}^T/\text{sq ft}}$
Fig. 7 allow 3.5 x 0.75 = $\underline{2.6\ {}^T/\text{sq ft}}$
Fig. 8 allow (5.6 x 0.75) + 2.9 = $\underline{7.2\ {}^T/\text{sq ft}}$
Use 10'-0"x10'-0" for interior footings

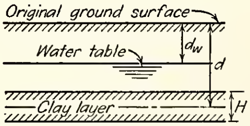
Figure 9





SETTLEMENT OF NORMALLY LOADED SOFT CLAY LAYER

1. Determine natural water content w of clay (% of dry weight)
2. Determine increase of pressure Δp (lb/sq ft) at mid-height of clay layer
3. Determine existing effective overburden pressure p_o (lb/sq ft):



d_w, d and H are expressed in feet

If water table is above ℄ of clay layer $p_o = 62d_w + 53d$

If water table is below ℄ of clay layer $p_o = 115d$

4. Determine $R = \Delta p/p_o$
5. Determine A from Curve 1 and value of w
6. Determine B from Curve 2 and value of R
7. Compute Settlement $S(ft) = H \cdot A \cdot B$

Figure 10

low the top of the surcharge, that part of the safe soil pressure due to the weight of the surcharge *(Figure 8b)* should also be reduced. The reduction should be 50 percent if the water level is at the top of the surcharge and a linear interpolation can be made to obtain the correction factor for water levels between the base of the footing and the top of the surcharge.

The soil pressures computed by these procedures are those that can be applied at the base of the footing in excess of the weight of the surrounding surcharge. Therefore, they may be regarded as net soil pressures. The illustrative example *(Figure 9)* will clarify the details of the computations.

If the footings rest directly upon clay, the average, unconfined, compressive strength should be determined for a depth beneath the footings equal to the width of the largest footing. The pressure q_a (tons per sq ft) at which the factor of safety against a bearing-capacity failure will be equal to three may then be computed by means of the equation

$$q_a = 0.95\ q_u\ (1 + 0.3\ \frac{B}{L})$$

in which q_u is equal to the unconfined compressive strength in tons per sq ft, B is the width of the footing in feet, and L is the length of the footing in feet. Inspection of this equation indicates that the safe load is approximately equal to the unconfined compressive strength.

If the safe load is less than about 1 ton per sq ft, it is probable that excessive settlements will develop even if the safety against a bearing-capacity failure is adequate. Therefore, footings on clays having an unconfined compressive strength less than about 1 ton per sq ft are not generally used, and some type of deep foundation is preferable. In some instances a raft may be suitable, provided the weight of the excavated soil compensates for most of the load added by the structure.

The principal source of settlement beneath a structure is likely to be one or more layers of relatively soft clay or other compressible soil at some depth below the footing level. Such a layer may lead to excessive settlement even if the footings or raft above it are established on dense sand or firm clay. Therefore, it is of the utmost importance to be able to predict the settlements that may occur if a structure is established above a stratum of compressible soil. The computation of the settlement requires the determination of the stresses at mid-height of each clay layer, due to the weight of the structure reduced by the weight of any excavated material. The computation of the stresses can be made accurately only by means of somewhat refined procedures but often a sufficiently accurate estimate can be made by assuming that the load is distributed from the level of the foundation through the subsoil at an angle of about 60 degrees with the horizontal. On the basis of this assumption, at least the average pressure at mid-height of each clay layer beneath buildings of ordinary dimensions can be estimated. In making such an estimate, only the dead load and that part of the live load that is likely to act upon the foundation most of the time should be considered. Loads that act only occasionally on the surface of the ground have little influence upon the settlement of clay sub-soils.

After the increase in stress at midheight of the clay layer has been determined, an estimate of the upper limit of the settlement can be made (*Figure 10*). The procedures are based on average values for the physical properties of soils; therefore, the diagram should not be relied upon to give precise results for all types of soil. Nevertheless, in most instances, the actual settlement of the structure will not exceed that estimated (*on the basis of Figure 10*).

If, after the appropriate computation has been made, it is found that a raft or footings of reasonable size cannot be used without danger of rupture of the subsoil or without danger of excessive settlement, then a deep foundation is indicated. The soil profiles will suggest that there are certain strong elements in the subsoil where it will be appropriate to establish foundations on piles or piers. Further studies may be required to determine the most appropriate type of a deep foundation, but the recognition of the necessity for such a foundation is the first and most important step in its design.

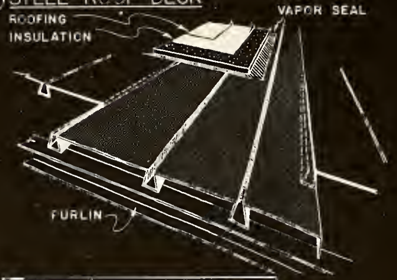
In this article, only subsoils consisting of sand, or of essentially saturated clays, or of layers of uniform clay have been considered. There are many materials such as partly saturated clays, partly saturated silts, and even saturated silts that do not follow the rules for either sand or clay. Therefore, the procedures outlined in this article must be regarded only as introductions to the scientific aspects of foundation design.

The foundation engineer must also regard subsurface conditions to a certain extent with the eye of the geologist. He must imagine what the characteristics of the materials are between the points where he has borings or samples. He must never assume that conditions are better than the poorest ones disclosed by any of the borings, unless geological conditions warrant such an unusual assumption. It represents sound judgment and economy to be a pessimist regarding the uniformity of soil conditions.

Finally the reader should appreciate that factors other than those considered in this article may be the controlling ones in selecting the type of foundations under certain conditions. In northern latitudes, for example, considerations of frost penetration and frost heave may be paramount. In the semiarid southwest, on the other hand, the volume changes in the soils due to shrinking and swelling with moisture-content changes during the seasons may be of far greater importance than the bearing capacity of the subsoil at any given moment. Hence the foundation engineer should always make an effort to acquaint himself with local peculiarities.

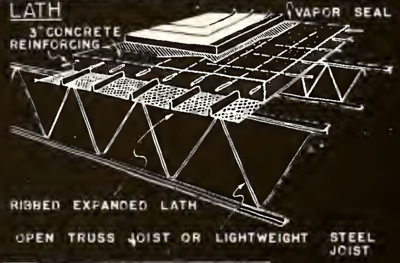
Indeed, one of the most important areas for research in the field of foundation engineering at the present time is the collection of data concerning the properties of soils and the behavior of foundations in various localities. The regional approach to foundation engineering is beginning to pay dividends and it is hoped that in the not too distant future there will be an atlas of information concerning subsurface conditions for various parts of the country in which the geological conditions are essentially uniform and where foundation problems are essentially similar. As information of this type accumulates, through the collection of quantitative data, the ability to design economical and safe foundations will also increase.

Ⓐ STEEL ROOF DECK



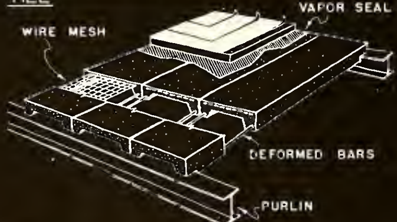
PURLINS = ABOUT 7'-0" O.C.
STEEL DECK = 18" X 1½" X VARIABLE

Ⓑ LIGHTWEIGHT CONCRETE ON METAL LATH



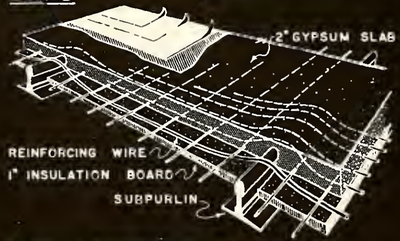
OPEN TRUSS JOIST
LIGHTWEIGHT " } = 2'-6" O.C.

Ⓒ LIGHTWEIGHT CONCRETE CHANNEL TILE



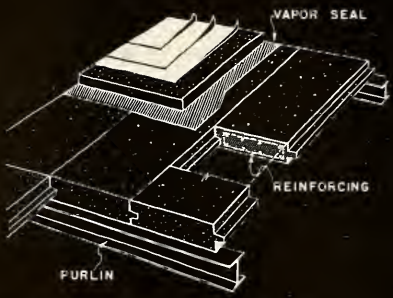
PURLINS = ABOUT 6'-8" OR 8'-0" O.C.
CHANNEL TILES = 24" X 2¾" X 6'-8"
24" X 3½" X 8'-0"

Ⓓ POURED GYPSUM ON INSULATION BOARD



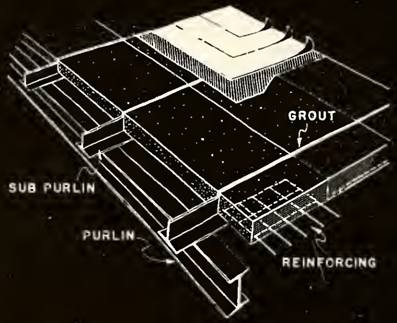
MAIN PURLINS = ABOUT 7'-0" O.C.
SUB PURLINS = " 2'-6" O.C.

Ⓔ LIGHTWEIGHT CONCRETE PLANK



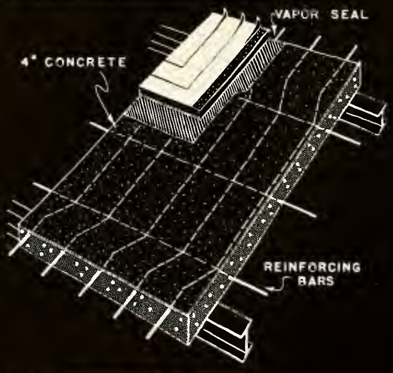
PURLINS = 7'-0" O.C.
CONCRETE PLANKS = 16" X 2" X 7'-0"

Ⓕ CALCIUM SILICATE TILES



PURLINS = ABOUT 7'-0" O.C.
SUB PURLINS = 36" O.C.
TILES = 18" X 2⅝" X 36"

Ⓖ REINFORCED CONCRETE



PURLINS = ABOUT 7'-0" O.C.

TABLE I: COST

Approximate cost per square foot for structural roof in place; roof membrane, insulation, beams, and hung ceiling not included in figure.

A	Steel roof deck	$0.30
B	Lightweight concrete on metal lath	0.38
C	Lightweight concrete channel tile	0.42
D	Poured gypsum on insulation board	0.43
E	Lightweight concrete plank	0.45
F	Calcium-silicate tile	0.55
G	Reinforced concrete	0.58

TABLE IV: FIRE RESISTANCE

Fire retarding needed to assure a "I-hour +" fire rating.

A	Steel roof deck	Entire ceiling
B	Lightweight concrete on metal lath	Entire ceiling
F	Calcium-silicate tile	Sub-purlins and beams
D	Poured gypsum on insulation board	Sub-purlins and beams
C	Lightweight concrete channel tile	Beams
E	Lightweight concrete plank	Beams
G	Reinforced concrete	Beams

TABLE II: WEIGHT AND SPAN

		Weight in pounds per square foot; roof membrane, insulation, beams, and hung ceiling not included.	Approximate span in feet under average live load.
A	Steel roof deck	3	7
F	Calcium-silicate tile	6	3 (with sub-purlins, 7)
D	Poured gypsum on insulation board	10	3 (with sub-purlins, 7)
C	Lightweight concrete channel tile	12	6'-8"
E	Lightweight concrete plank	13	7
B	Lightweight concrete on metal lath	15	2'-6" (with sub-purlins, 7+)
G	Reinforced concrete	50	7 to 10

TABLE V: CONDENSATION

Relative humidity at which condensation will start for various U-factors (see Table 3) at the fixed conditions of 70° F indoors, 0° F outdoors.

U-factor	Relative humidity %
0.10	87
0.20	77
0.30	64
0.40	56
0.50	47
0.60	40
0.70	35
0.80	30
0.90	20

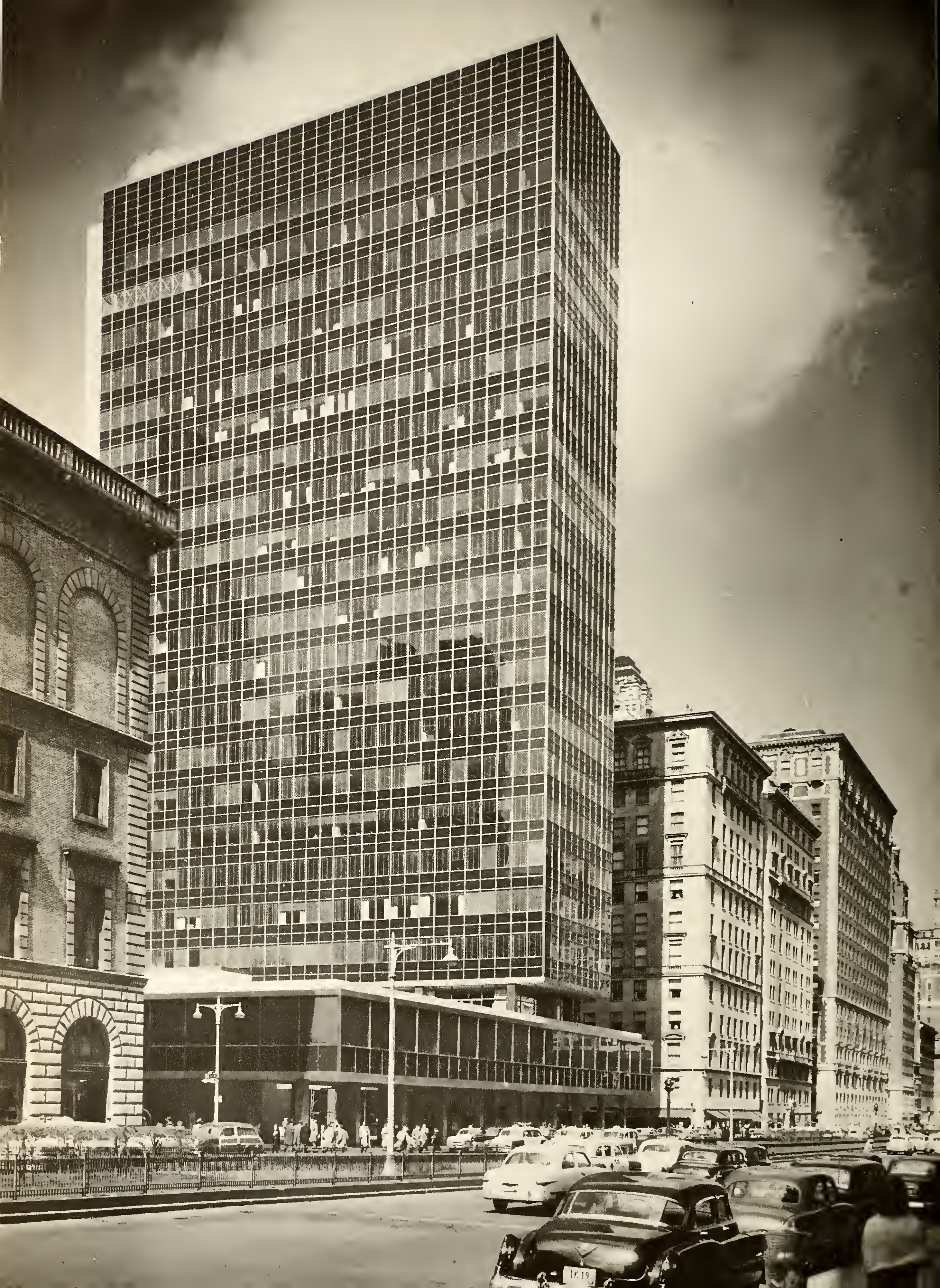
TABLE III: HEAT LOSS TRANSMISSION

U-factor, Btu/hour/square foot/1° F difference in temperature, indoors and outdoors; roof membrane included, but not ceiling.

		No additional insulation	1" rigid insulation	2" rigid insulation
D	Poured gypsum on insulation board	0.19	0.12	0.09
F	Calcium-silicate tile	0.19	0.13	0.10
E	Lightweight concrete plank	0.54	0.20	0.13
C	Lightweight concrete channel tile	0.66	0.22	0.13
B	Lightweight concrete on metal lath	0.69	0.22	0.13
G	Reinforced concrete	0.72	0.23	0.13
A	Steel roof deck	0.95	0.25	0.14
	Comparison factor, greatest loss/least loss.	0.95/0.19=5	0.25/0.12=2.1	0.14/0.09=1.6

CONSTRUCTION MATERIALS DATA

Obviously, to insure satisfactory, economical construction the designer must have a thorough knowledge of the properties and characteristics of materials as well as an understanding of how they can be used to best advantage. Most manufacturers offer accurate information concerning the performance of their particular product. Relatively few, however, give us precise comparative data between their product and others serving in a like capacity. Thus it becomes the responsibility of the individual practitioner to develop for himself reliable information of this kind for ready reference. A good guide for such a study may be found in these illustrations and tabular data (*acrosspage and above*). Developed by Prof. William J. McGuinness this specific data provides a valuable and useful comparative analysis of material commonly found in industrial roof construction. Although a study of this type requires valuable time and must frequently be made in conjunction with a manufacturer's agent, architect, consulting engineer, and general contractor, the rewarding payoff comes the next time one must consider the most appropriate materials for a particular set of conditions. In the following articles, much data on specific applications of various building materials is offered.



UBIQUITOUS STEEL

Steel in its various forms is one of the most familiar materials seen in building construction. Because of its many advantages, stainless steel has been increasingly useful in commercial buildings. The new 525 William Penn Place Building, Pittsburgh, is one of the largest commercial structures to employ stainless steel on such an abundant scale (Harrison & Abramovitz, architects). Among its "firsts" were the largest single order of stainless-steel spandrels ever pressed (*page 15*), the first major installation of formed stainless-steel window frames, and the first extensive use of decorative stainless-steel fins. (Other outstanding developments in carbon steel are also evident. Major savings in the total building weight—as much as 75 percent in the case of partitions—were effected through the use of steel-panel walls and cellular-steel floors.) In the main lobby, wall paneling, elevator corridors, and doors are all brushed-chrome steel; further, all of the irregularly-shaped beams and free-standing columns are also sheathed with the same metal. Many innovations are to be found in the captive kitchen which hotel authorities consider to be a model installation. In New York, slab-like Lever House (*acrosspage*) is probably the best known example of major uses of stainless-steel in a commercial structure. On its four elevations, glass and stainless-steel mullions extend vertically for the full height of the building, and horizontally completely envelop the slab. At its open ground-floor level, stainless sheet encloses the structural columns (continuously subjected to pedestrian abuses) so that no painting will be required and only the simplest of maintenance is necessary.

In 1934, only 55,907 tons of stainless-steel ingot were produced. By 1953, however, an all time high of 1,015,303 tons was reported by the American Iron and Steel Institute (based on 20 producers representing 97 percent of the total output). This record was established in spite of a decline in shipments of this metal to the aviation industry and a 30 percent drop in government demands. Architectural uses and a greater usage by the automotive industry contributed largely to the record year. Stainless steel in the architectural field was up 47 percent due to increased use in *store fronts* and *building entrances*. Richard Paret discusses the fundamental principles governing the selection, specification, and installation of stainless steel in store front design in his timely article (*page 127*).

Stainless Steel Applications

BY RICHARD E. PARET*

Increasing acquaintance with the stainless steels for varied architectural uses is resulting in development of a number of new applications, in the design of exteriors as well as interiors of buildings.

Exploration of the possibilities of this "new" metal has grown rapidly since the end of World War II. Its appeal to present-day architects is based in the main on four characteristics—resistance to corrosion, great strength in relation to comparable materials, lasting beauty of finish, and economy.

Postwar shortages of stainless steel have now been overcome to a considerable degree; its availability in sheet or strip form has currently stimulated interest.

The term stainless steel denotes a large family—a group of some 30 alloy steels which resemble each other, yet differ widely in their properties and uses. The family resemblance is based upon the fact that all the stainless steels contain chromium in addition to the iron and carbon present in all steels. It is the chromium in this combination that makes the steel stainless. The chromium joins with oxygen in the air to form an oxide on the surface—a microscopic film that protects the metal from rusting and discoloration.

If the protective film is scratched or broken, it forms again just as soon as the metal is exposed to the oxygen present in ordinary atmosphere. The chromium in stainless steels also resists corrosion and discoloration when the metal comes in contact with various acids and alkalis.

All stainless steels contain at least 11.5 percent chromium. When other elements are added, the character of the stainless steel undergoes a change. Nickel, for example, makes it stronger and more ductile, so that it can be more easily cold-worked and formed into a great variety of shapes at ordinary room temperature.

Nickel also increases resistance to scaling at high temperatures, reduces grain growth, and lessens embrittlement after long exposure to high temperatures. Its presence results in an alloy of the stable austenitic type; highly resistant to impact, nonmagnetic, with extraordinary toughness, and with no capacity for hardening under heat treatment.

Other elements impart still other special qualities. Molybdenum, for example, increases the ability of stainless steel to resist corrosion by reducing pitting under severely corrosive conditions.

stainless steel types

No single analysis of stainless steel satisfies all the requirements of the 100,000-odd applications to which the metal is put. About 30 compositions of stainless steel in common use have been compiled by American Iron and Steel Institute and given type numbers for purposes of identification.

For architectural applications, Types 301, 304, and 316 are usually

Stainless Steels—A.I.S.I. Types: Chemical Composition Limits and Ranges

	Chemical composition, per cent							
Type Number	C	Mn Max.	Si Max.	P Max.	S Max.	Cr	Ni	Other Elements
301	Over 0.08/0.20	2.00	1.00	0.040	0.030	16.00/18.00	6.00/8.00	—
302	Over 0.08/0.20	2.00	1.00	0.040	0.030	17.00/19.00	8.00/10.00	—
304	0.08 Max.	2.00	1.00	0.040	0.030	18.00/20.00	8.00/11.00	—
316	0.10 Max.	2.00	1.00	0.040	0.030	16.00/18.00	10.00/14.00	Mo 2.00/3.00
430	0.12 Max.	1.00	1.00	0.040	0.030	14.00/18.00	—	—

Stainless Steel Properties: Annealed Sheet and Strip

AISI Type	Tensile strength psi.	Yield strength (offset: 0.2%) psi.	Elongation in 2 in. percent	Modulus of elasticity in tension psi.	Cold bend degrees	Mean coefficient of thermal expansion: 32° to 212° F
301	110,000	40,000	60	28×10^6	180	9.4×10^{-6}
302	90,000	40,000	50	28×10^6	180	9.6×10^{-6}
304	85,000	35,000	50	28×10^6	180	9.6×10^{-6}
316	90,000	40,000	50	28×10^6	180	8.9×10^{-6}
430	75,000	45,000	25	29×10^6	180	5.8×10^{-6}

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* *Stainless Steel Specialist, American Iron and Steel Institute.*

Upper left: looking toward barber shop in basement lobby, Terrace Plaza Hotel, Cincinnati, Ohio. All glass frames, display cases, and facings on column at right are of stainless steel. Above: exterior view of Gourmet Room on roof of Terrace Plaza Hotel. Door frame, window mullions, railing supports, and bands at top and bottom of windows are of stainless steel. *Photos: Ken Rarich*

specified by the designer, according to individual uses as a structural material or for decorative purposes. For example, Type 301 normally is used where thin, relatively high-strength material is desirable, such as in roof drainage equipment, some facia work, and the like.

For general architectural application, Type 302 or 304 is ordinarily specified. The choice between these two is based upon the amount of welding to be done, and upon whether the material is to be used for interior or exterior work. Type 302 is frequently used for interior trim or constructions, welded or unwelded. It is also deemed satisfactory for exterior trim where there is a minimum amount of welding and relatively mild atmospheric corrosion. Where any darkening parallel to and near the weld is to be avoided, Type 304 is considered more suitable.

Where very severe corrosion conditions are encountered, as in seashore locations, Type 316, which contains a small amount of molybdenum, is usually specified. On many buildings Type 430 has been used, but because of a slight difference in corrosion-resistant properties, those mentioned above are generally preferred.

economic factors

Taking advantage of the high tensile strength and the toughness of stainless steel, designers are now extending the use of extremely light-gage sections, assemblies, and panels for structural purposes, resulting in considerable economy. The absence of expense factors which would be involved in repairs, replacements, polishing, or other maintenance items means that the first cost is also the last for stainless steel applications —an important consideration for the building owner.

The metal is available in the conventional forms, sheets, strips, bars, wires, tubular sections, and some structural sections, and in a wide range of dimensions, so that standard sizes and shapes are obtainable from regular jobber or warehouse stocks.

mechanical properties

Stainless steel has a high weight-strength ratio. To take Type 302, the commonly used stainless which contains 18 percent chromium and 8 percent nickel, as an example, this metal has a specific gravity of 0.286. Either as 24-gage sheet or as round bar stock up to 2-inch radius, its ultimate strength when annealed is 85,000 psi., its yield point is 35,000 psi., and its modulus of elasticity is 28,000,000 psi. Strip of this designation, cold-rolled to 150,000 psi. of ultimate strength, will stand a 135-degree bend across the grain of the metal and 135 to 180 degrees with the grain.

fabrication

Either stainless steel sheet or strip of the chromium-nickel types lends itself readily to cold-forming in the fabrication shop because of its high ductility. In the softer tempers it may be bent flat on itself without danger of breaking or edge-cracking in thicknesses up to ¼ inch. These types are much stronger and work-harden more rapidly than mild steel, however, and thus require greater power. Because of the metal's high yield strength the springback is roughly twice that of mild steel. If the fabricator has not been accustomed to working with stainless, he should be warned to protect the finish. By applying adhesive tape, plastic coating, or strip-off adhesive paper to the points where it will come into contact with metal tools, he can prevent scratching or marring.

Cutting of stainless steel requires only the usual tools and equipment found in a fabricating shop; however, because of the metal's strength and toughness, the cutting requires more power than mild steel. It may be sheared, sawed by hand, power,

Below: Stainless steel curtains hung between elevator lobby and reception room of Monsanto Chemical Company's offices, New York City. Standard 3/32" chain mesh, made from 19-gage wire, was specified. Vertical edging sections are also of stainless steel. Curtain, suspended from an overhead track, can be closed and locked at center.

Above: downspout assembly showing details of stainless steel straps. Left: stainless steel walls in a beer cooling room of the Schlitz brewery, Milwaukee, Wisconsin.

abrasive cut-off wheels, or cutting torches, as well as punched, perforated, drilled, or tapped.

Joining of stainless steel by welding, riveting, or soldering calls for the conventional equipment. It may be welded by electric resistance, electric arc, acetylene or atomic hydrogen methods, but not hammer-welded. The chromium-nickel types have a coefficient of thermal expansion 50 percent greater than mild steel and a heat conductivity about a third as great. Thus, in order to prevent warpage, planned sequences of welding operations, jigs, or adequate means of drawing off heat should be employed. Type 430 stainless steel welds are not as ductile or resistant to shock as welds on the 300 series.

For welded work which is to be placed in locations subject to high atmospheric corrosion, stainless steel Types 304 and 316, modified to contain a maximum carbon content of .03 percent, are now available.

In riveting stainless steel sheets and plates, preferably rivet holes should be drilled, but may be punched. Holes should be clean of burrs; on plates ½ inch and up in thickness, it is advisable to chamfer the hole. Chromium-nickel stainless steel rivets up to ¼-inch diameter may be driven cold. Above that size, they should be heated to between 1950 and 2050F and set before they cool below 1800F. Riveting is not ordinarily recommended because of the excellent weldability of stainless steel and the uniformity with which weld metal can be blended into the parent material.

Welding rather than soldering is recommended for utmost strength and tightness. Stainless steels may be soft-soldered to produce tight and hermetically sealed joints; however, they will give a relatively low-strength joint. Edges to be joined should be lock-seamed, spot-welded, or riveted for strength, and then soldered to seal the seam. Sheets having a smooth cold-rolled finish or a highly polished finish should be roughened to produce good adhesion.

Surface finishing in the fabricating shop is sometimes desirable, particularly on welded jobs. Cloth buffs for grinding and polishing usually are employed with abrasive heads, or factory-coated abrasives may prove simpler to use. Aluminum oxide as an abrasive lends itself to all grinding and polishing operations on stainless steel. The type of finish desired may be controlled by the use of lubricants with the abrasive. For bright-luster surfaces, buffing follows the polishing operation.

cleaning

Unnecessary cleaning of stainless steel can be eliminated by keeping the work covered during fabrication operations whenever possible. Tiny tool fragments or other substances, when picked up may cause superficial discoloration. Chemical cleansing or passivation before delivery is recommended. This consists of immersing the work in a 20 percent nitric acid solution at 120F for 15 to 30 minutes. Remove and wash thoroughly with water. On large assemblies, the acid solution may be swabbed on with a brush, this operation to be followed by thorough washing with water.

Stainless steel is easily cleaned with ordinary soap and water. Light discolorations may be removed with household cleansers. Heat tints and other blemishes may be removed with stainless steel wool, never ordinary steel wool.

scope of applications

The combined decorative and protective features of stainless steel place it generally in the same fields as the other light-gage metals used in the building arts—carbon steel, aluminum, copper, brass, tin alloys, and porcelain-enameled steel. Its peculiar properties of resistance to heat and to corrosion due to weather have proved of major interest. The principal types of installations include exterior and interior trim of light-occupancy buildings; working areas such as kitchen, laundry, and bathroom of private homes; restaurants and hotels; roof drainage; and insect screening. A new application which is experiencing rapid development is as exterior curtain walls in multistoried buildings.

exterior trim

Stainless steel is used for mullions, sheathing, window trim, doors, marquees, letters and numerals, and facia. It is also adaptable to spandrels and has been effectively employed for flagpoles, spires, and the like.

Among the early installations of stainless steel mullions were those on the Chrysler and Empire State Buildings, both now about 20 years old, a sufficient time to demonstrate the practical and economical nature of the metal for this purpose. When an airplane crashed into the Empire State Building in 1945, a selection of a mullion was removed; on examination this piece of Type 304 stainless steel, .050 in. thick, showed no evidence of pitting or other damage to the surface and on being washed with ordinary soap and water resumed its high luster. Each year a committee of the American Society for Testing Materials makes an inspection of mullions on the Chrysler Building, Empire State Building, Philadelphia Savings Fund Society Building, and others. The reports have uniformly described an absence of corrosion or other deterioration.

Similar history is provided by

other types of exterior trim. In 1949, the doors of the Empire State Building were replaced by stainless steel doors, in order to eliminate further maintenance and replacement costs.

interior trim

Decorative moldings and doorways, elevators and elevator doors, lobby and foyer walls, counters, and furniture are among the interior building uses of stainless steel. The installations range from apartment houses to office buildings and from theaters to department stores. It has wide application in bank buildings, particularly for vault and safe doors, trim, and tiers of boxes in safe deposit departments. In hospitals, stainless steel walls and ceilings for operating rooms, therapy rooms, diet kitchens, and pantries are finding increasing acceptance because of sanitary features.

roof drainage

Deterioration of roof drainage equipment for dwellings, commercial, and industrial buildings has long presented serious problems. Roof gutters, downspouts, conductor pipe and flashings demand adequate protection against atmospheric corrosion, particularly in seaboard locations where the air is laden with salt particles held in suspension. In most parts of the country, roof drainage systems also must be strong enough to withstand heavy snow and ice loads without sagging. Other hazards include rotting leaves, birds' nests and droppings, acrid soot and cinder deposits, heavy smoke accompanied by fog, sleet, and hail, and acid or alkali fumes. Maintenance cost is reduced if the drainage equipment does not discolor in service and "bleed" onto adjacent surfaces.

Stainless steel roof drainage equipment provides excellent protection against deterioration. Installations 10 to 12 years old, backed by scientific test data prepared by the A.S.T.M. and International Nickel Company, have established an excellent record of endurance.

In the following table are given the average yield strengths of materials commonly used for roof drainage systems:

Material	*Yield Strength Psi.*
Type 301 Stainless Steel (annealed)	40,000
Galvanized Iron	28,000
C. R. Copper (5%-6% cold reduced)	20,000
Soft Copper, sheet or strip	10,000
Aluminum 3S (½ hard)	20,000

Left: installation of a stainless steel mullion in the Universal International Building, New York City.

Right: construction view of stainless steel curtain wall exterior of the Turbine Building, General Electric Company, Schenectady, New York.

The extra strength of stainless steel permits it to withstand heavy ice and snow loads without sagging, to resist buckling and cracking due to extreme temperature changes, and to resist denting and crushing during shop fabrication and erection. This extra strength also permits the use of lightweight sections, with resulting economy in material and erection costs. The neutral color and enduring luster of stainless steel add to its appearance value.

insect screening

A stainless steel screening, recently brought to market, meets architectural requirements of strength, prevention of clogging of the mesh, and inability to "bleed" onto surrounding surfaces. The strength factor has made it possible to reduce the diameter of the wire used, by several thousandths of an inch. This strength insures against bagging and other deformation or damage through normal wear or misuse. The wires resist stretching, which enables the screen to be pulled tight.

Visibility through the screen also has been increased, by use of the finer wires. This high visibility remains constant with the passage of time, because there are no loose corrosion products to clog the mesh, and painting is not required. Type 316 stainless steel screening, subjected to tests by International Nickel Company, reported through the A.S.T.M., withstood years of exposure longer than other screening materials. In industrial and sulfurous atmospheres, screens of Type 316 showed no failures. Complete failure of the next most enduring material occurred in from five to eight years.

curtain walls

Perhaps the most important new development in the use of stainless steel in the architectural field is that of the curtain wall, designed to replace the masonry wall common in multistory buildings. The wall does not merely act as a weather facing; panels of "sandwich" construction are built, consisting of fluted sheets of 18-8 stainless steel on the outside and flat carbon steel sheet on the inside, with a core of insulation between. It is claimed that the panels, which are 3″ or 4″ thick, are superior in thermal insulation value to a 12″ masonry wall with furred plaster interior. They offer the further advantages of increased floor space, fast construction, elimination of cold-weather construction problems, and marked savings in maintenance and depreciation costs.

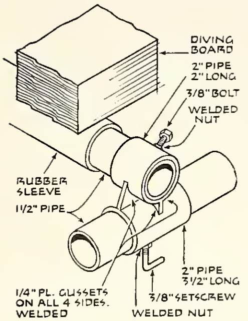
The first large office building using this construction was recently completed for General Electric Company, in Schenectady, New York, to house offices for its turbine division. Several other large office buildings employing stainless steel panel curtain wall construction are now in the design stage.

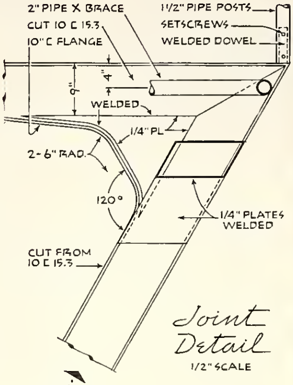
**See Selected Detail of stainless steel curtain wall on p. 14.*

Swimming Pool: Diving Platform

Fulcrum Detail

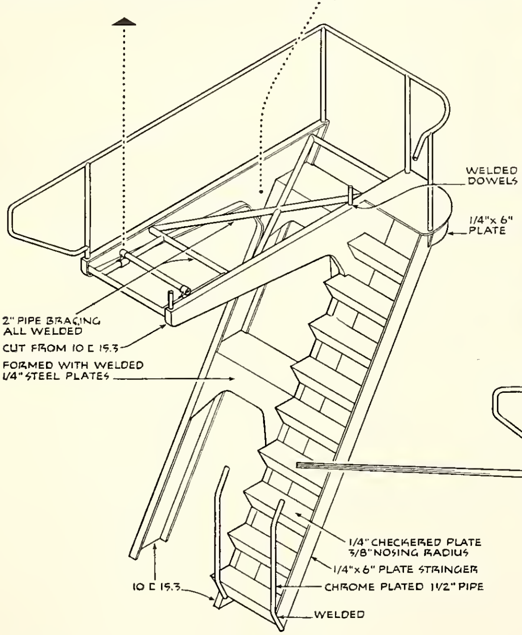
SCALE 1 1/2" SCALE

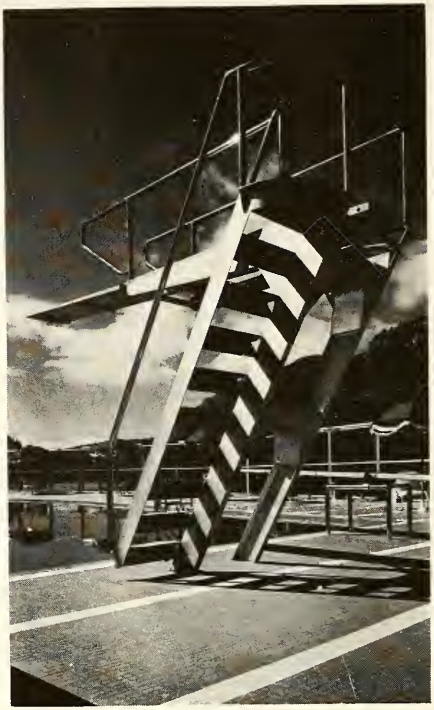




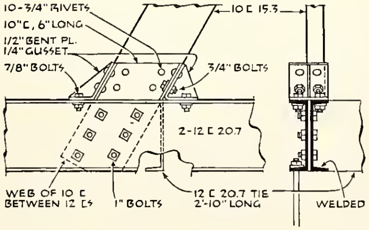
Joint Detail

1/2" SCALE

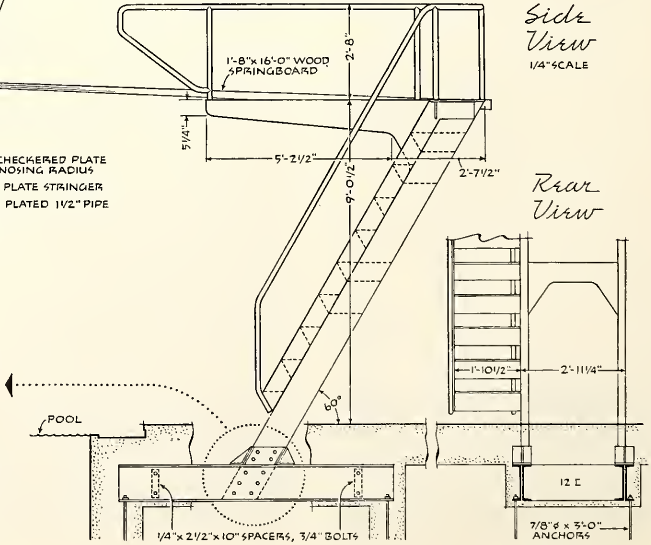

WELDED DOWELS
1/4"x 6" PLATE
2" PIPE BRACING ALL WELDED
CUT FROM 10 C 15.3
FORMED WITH WELDED 1/4" STEEL PLATES
1/4" CHECKERED PLATE 3/8" NOSING RADIUS
1/4"x 6" PLATE STRINGER
CHROME PLATED 1 1/2" PIPE
10 C 15.3
WELDED



PHILIP FEIN



Detail at Base 1/2" SCALE



Side View

1/4" SCALE

Rear View

BROADMOOR HOTEL

Colorado Springs, Colorado

BURNHAM HOYT

Architect

Data on Stainless Steel Store-Front Design

BY RICHARD E. PARET*

An increasing use of stainless steel for store fronts has greatly improved the design techniques and methods of erection for this material. In addition, the many types of stainless steel and the variety of finishes available offer the architect considerable freedom for design expression. Numerous stock components, as well, are at the disposal of all designers.

The use of this material significantly reduces the cost of store maintenance, as its original appearance is readily retained with soap and water washing; time consuming chemical cleaning and polishing are eliminated. Usually, this single saving offsets the difference in first cost between stainless steel and less durable or less easily cleaned materials. The strength, toughness, and corrosion resistance of stainless steel give it a long, useful life. As labor and replacement costs continue to rise, this durability pays progressively greater dividends.

The different ways that the architect may use stainless steel for store front design are legion, as ease of workability adapts the material to many shapes and forms. The designer may use custom, shop-fabricated designs; stock, factory-made components; or a combination of both.

design standards

Store front construction is generally executed by either of two trades. Designs with custom-made components call for the work of architectural metal fabricators. These are perhaps the most skilled of the sheet metal workers—adept at the use of relatively heavy materials and skilled in handling bars and tubing as well as sheet metal.

Where this type of craftsman is not available, or where a design using factory-made components is more suitable, installation may be performed by mechanics associated with the glazing trade. Generally, these men are equipped for and skilled at cutting and installing pre-formed shapes. In most cases they do not have equipment to make special sections, but must secure them from manufacturers of prefabricated components.

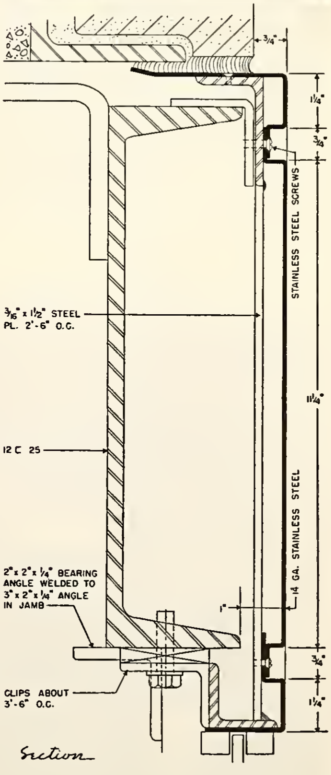
Almost all mullions, muntins, sash, sign letters, and the like, are sheet metal elements which convey the appearance of solid metal. These surface coverings are designed to protect other structural members, or to save weight and material; obviously they cost far less than solid pieces. Furthermore, the innate durability of stainless steel makes thin sections entirely adequate.

A desirable design requirement for sheet and strip of stainless steel, or any other reflective material, is that flat areas be kept flat. Several procedures have been developed to prevent occurrence of wavy reflections:

1. It is essential to employ sufficiently heavy-gage metal in each application. Required thickness depends upon the panel size, the presence or absence of bends for stiffness, vulnerability of the part to kicking, pushing, or bumping, and, finally, how closely the part may be scrutinized by passers-by.
2. Avoid the use of screws or fasteners that pierce exposed flat areas. Panels should be crimped or bent at the edges; screws through the lip or offset can be concealed and the bent shape can be designed to isolate any deflection caused by drawing these screws up tight.
3. Panels may be backed with plywood or other materials to augment the stiffness of thin metal.

A great deal of the dirt that settles on stainless steel can be washed away by rain. Few materials approach this ability to stay clean and smooth when exposed to the elements. With careful design, it is possible to capitalize on this quality by using shapes that are at least partially self-cleaning. Dirt-catchers such as crevices, inaccessible ledges, pockets and the like, should be avoided whenever possible. It is desirable to prevent soiling of ornamental stainless steel

Photo and detail below—break-bent, recessed channel grooves add stiffness to this window head panel; screws located in grooves can be tightened without deforming the flat sheet. Other windows in this structure have awning-box covers of the same design. Mutual Life Insurance Company Building, New York; Architects, Shreve, Lamb & Harmon.



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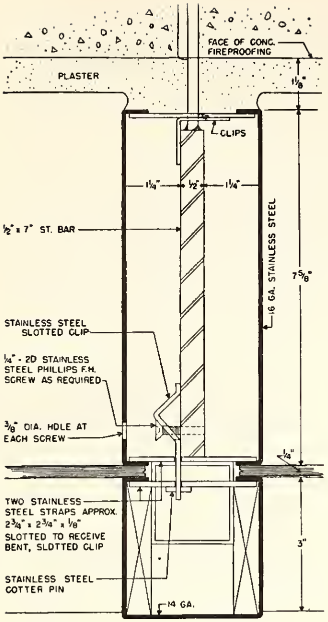
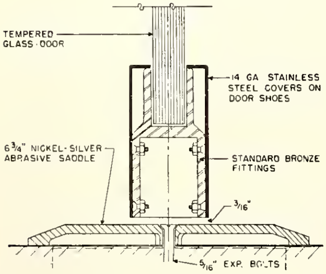
* *Stainless Steel Specialist, American Iron and Steel Institute.*


FACE OF CONC. FIREPROOFING
PLASTER
1⅛"
CLIPS
1¼"
½"
1¼"
½" x 7" ST. BAR
16 GA. STAINLESS STEEL
7⅝"
STAINLESS STEEL SLOTTED CLIP
¼" - 20 STAINLESS STEEL PHILLIPS F.H. SCREW AS REQUIRED
⅜" DIA. HOLE AT EACH SCREW
¼"
TWO STAINLESS STEEL STRAPS APPROX. 2¾" x 2¾" x ⅛" SLOTTED TO RECEIVE BENT, SLOTTED CLIP
3"
STAINLESS STEEL COTTER PIN
14 GA.

Plan

Above—straps and slotted wedging clips fasten this stainless steel mullion to the structural framing and, at the same time, cradle the glass in a resilient mounting. Small holes for screwdriver access are the only visible evidence of an assembling device. To avoid possible staining and to assure easy glass replacement whenever necessary, all straps and clips are made of stainless steel—usually from trimmed ends that would otherwise be scrap.


TEMPERED GLASS DOOR
14 GA STAINLESS STEEL COVERS ON DOOR SHOES
6¾" NICKEL-SILVER ABRASIVE SADDLE
STANDARD BRONZE FITTINGS
³⁄₁₆"
⁵⁄₁₆" EXP. BOLTS

Section

Above—stainless steel covers are anchored to cast bronze door shoes to provide durability and color-match with other stainless steel trim. This method of application is suitable for an assembled door; screws, spotwelded to the cover, engage nuts inside the casting. Other and simpler fastening systems can be used if the shoes are available for machining before the door is assembled.

by carrying away the unavoidable wash-down from higher parts of the building through appropriate drains.

Very often, the difference between mere adequacy and real distinction in a stainless steel store front grows out of the appropriate use of surface finishes and metal textures. Stainless steel sheets can be purchased in a wide range of mill finishes, from dull to a high polish. The stock is also furnished with embossed, textured surfaces in a number of patterns. Perforated stainless steel is also available. This choice of surface treatments can be used to avoid monotony, to accent focal points, and to suggest depth in the fundamental shapes which the architect conceives.

surface finishes and textures

Commercial mill finishes on stainless steel sheets are designated by number. A No. 2 finish is cold rolled and receives no added polishing at the mill. No. 2-D is dull with a nonreflective, matte surface. No. 2-B is brighter, yet its sheen is also quite diffused.

The No. 4 finish—polished but not extremely reflective—finds general application in store-front work. It is, perhaps, the finish most suitable for further polishing after shop work has been completed on formed parts. Such terms as "satin polish" are used to designate finishes achieved by the stainless steel fabricator or installer on formed pieces. Interpretations of such finish designations may vary; the most satisfactory way to specify shop finishes is by comparison with samples provided by the fabricator.

The No. 6 finish on stainless steel sheet has a velvety, brushed sheen. This is another dull, matte surface, like the No. 2-D cold rolled finish, but is more even and uniform. The metal is first polished, then tampico brushed to obtain a subdued luster.

A No. 7 finish is a high polish. It is very reflective—almost mirrorlike. This is the smoothest surface usually furnished commercially in stainless steel sheets.

The polished surfaces, No. 4 and No. 7, are recommended where metal is repeatedly rubbed by hands or clothing. Their use avoids burnished bright spots at the points of greatest wear.

Textured or embossed stainless steel comes in a number of patterns. Some are coarse and knobby—others are extremely fine. The widths of textured sheets or strips are governed by the widths of the rolls used to do the embossing; the widest is about 36 inches.

Such products as stainless steel screen or perforated and expanded metal are useful for auxiliary walls, grilles, and sign details. Screening is available with bars as large as ¼-inch diameter and down to insect screen or finer. Perforated stainless sheets can be obtained not only with plain round holes but also with a variety of shaped hole patterns. Expanded metal—the same type of product as metal lath—has a great deal of distinction when it is made in stainless steel; both coarse and fine meshes are available. Expanded metal can be rolled flat to smooth the ridges formed when slits are stretched open.

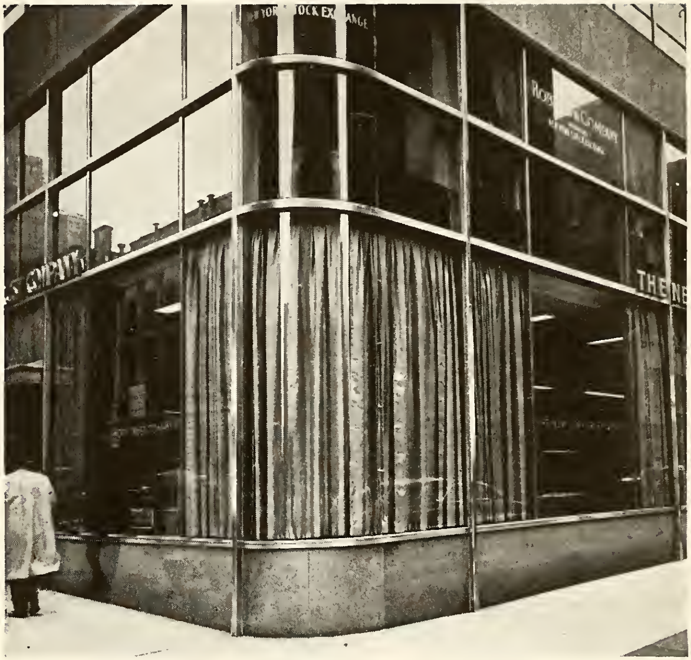
shop-fabricated store-front pieces

Stainless steel is easy to work with standard sheet-metal tools. However, more power is required than for other architectural metals, as stainless steel is stronger. The metal's mechanical stability is an assist when rigidity is required for thin, formed pieces.

With the somewhat outdated exception of blacksmiths' forge welding, stainless steel can be worked, formed, and joined by any method practicable for ordinary steel and iron. While this wide freedom of method is very important in industrial applications and in basic architectural developments like the curtain wall, store-front designs usually narrow the shop requirements down to a point where shearing, brakebending, and drilling or punching holes are the predominant operations.

Immediately below — both prefabricated sections and shop-built pieces are found in this bank front; the special mullion design is presented in detail drawing acrosspage.

Bottom of page — stock sash sections have no visible fastenings on the exterior side of the plate glass; set screws (which are located on the interior side of the window and can be seen in photo) draw up the assembly mechanism which cradles the glass. 488 Madison Avenue, New York; Architects, Emery Roth & Sons.



With a bending brake, the fabricator can produce an almost limitless variety of special formed sections. He can jog the edges of flat panels for concealed screws, form panels for design effect or stiffness, make box sections, attain quilted patterns and perform a host of similar operations.

The makers of stainless steel signs take full advantage of the metal's workability in building block letters out of thin stock. At first these assemblies are tack welded to hold the parts together; later, the joints are usually soldered for a weather seal.

Although intricately formed shapes are often needed for parts and letters of signs, most stainless steel members for entrances and fronts are designed with very simple, plain lines. It is well, for economy's sake, to remember the more common shop operations—shearing, sawing, bending, etc.—in order to keep the design of each piece suitable for a routine series of familiar shop procedures.

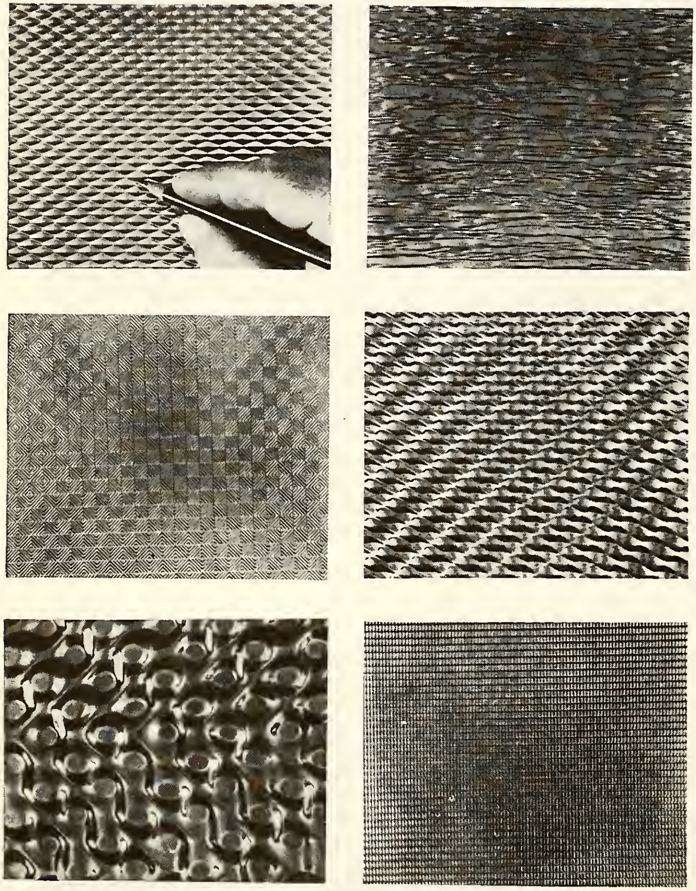
factory-made stainless steel components

Well-engineered sash, mullions, and other glass-setting members, are furnished in stainless steel by a number of manufacturers. These pieces are made, not by brake-bending as in job-shop practice, but by continuous roll forming. Wide, formed bands, and narrower, interlocking strips are made for fascia sheathing. Many other kinds of general-purpose and special sections are also roll formed.

The stock sections designed for use with glass may be obtained in a variety of shapes—either for single or double glazing. Built-in spring devices cushion the glass in a resilient mounting; screws are completely concealed on the exterior side. This design permits easy glass installation, or replacement if necessary.

The suppliers of prefabricated store-front components in stainless steel offer a detail design service that can make an architect's task

Below—textured patterns are embossed on stainless steel sheets. Known to the trade as "Rigidized" metal, this product offers a wide variety of surface designs. All illustrations are at the same scale.



considerably easier. After the architect has laid out the general scheme and arrangement, indicated relationships of elements to the basic building structure, and specified the type of sections and panels desired, the supplier of materials will prepare full-scale details and assembly drawings. These drawings specify all stock parts, methods of fastening, and necessary information for making special individually-fabricated pieces where required.

Roll-formed sections in hundreds of different shapes are also produced by concerns not directly associated with store-front construction. Stainless steel tubing—either round or formed into rectangles, ovals, and special contours—can be purchased from a number of suppliers.

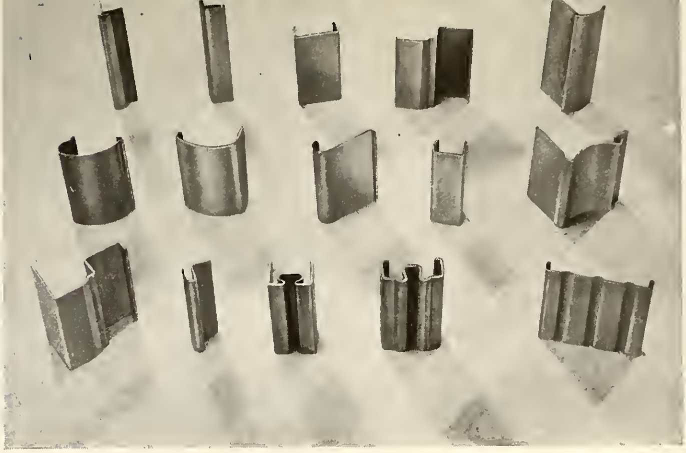
Composite panels are made with thin stainless steel sheets bonded to plywood, composition board, insulation, etc. The stainless steel on one or both sides may have dull, polished, or a textured surface. These panels gain rigidity and flatness for relatively large areas without the weight or expense of heavy-gage metal, which would be necessary for good appearance in most conventional large-panel designs.

Stainless steel doors and door frames are available in practically every style—tempered glass, paneled, revolving, etc. Usually, the makers of stainless steel doors stock standard parts and formed tubular sections from which they make up doors and frames on order to specified dimensions.

use stainless hardware

The wide variety of stainless steel screws, bolts, sheet-metal screws, etc., that are made today fill the needs for both exposed and concealed fasteners. Exposed screw heads, of course, should be stainless for good appearance, uniformity of color, and easy cleaning.

Right—these sections, produced by forming rolls, are made in continuous lengths and can be cut to size as needed. Thousands of shapes fill requirements for moldings, protective strips, glass-setting components, interlocking fascia panels, and decorative trim.



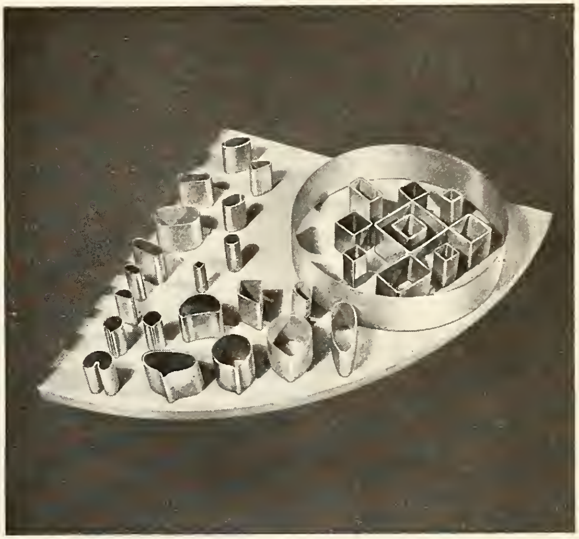
It is important to specify stainless steel fasteners for concealed work as well. If nails, screws, or bolts that hold stainless steel pieces are made of plated or ordinary steel, unsightly staining with rusty streaks may mar exposed surfaces. Such difficulties have occasionally given rise to undeserved complaints about rusty or inferior stainless steel; however, in all cases this streaking was caused by corroding fasteners which should have been of stainless steel even though they were concealed from view.

Door-pulls, handles, hinges, and similar hardware items are supplied in stainless steel. Other parts, like locks, are made of a white nickel-bronze alloy which matches the stainless steel color.

what types of stainless steel to use

Stainless steels are a family; there are about thirty standard types and many special variations. Producers use many proprietary designations for standard types, but all recognize American Iron and Steel Institute type numbers, established as a "shorthand" method of communicating technical information throughout the industry. The most familiar stainless steel, Type 302, 18 percent chromium and 8 percent nickel, is recommended for most store-front work. Where direct seacoast exposure, as along ocean boardwalks, makes for a severely corrosive atmosphere, Type 316 is a better choice. This stainless steel grade contains a higher percentage of alloying elements, and it resists corrosion under extremely difficult conditions.

Type 430, which contains chromium, but not nickel, is used occasionally in store-front design. It may be expensive to maintain in any but a dry, nonindustrial, inland climate, and is generally recommended only for interior structural and decorative work.



Above—sections of stainless steel tubes in a variety of shapes; round, polished tubing can be cold-drawn or rolled into special forms without spoiling the finish.

Below—samples of prefabricated sash, mullions, transom bars, and fittings for display windows. Products of several manufacturers are represented.

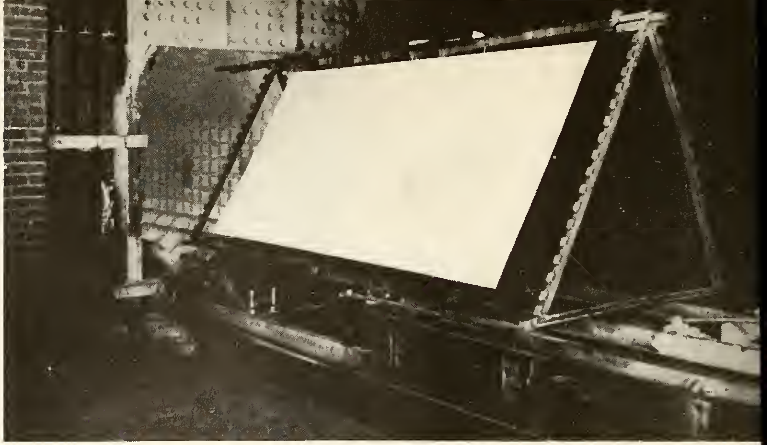


Figure 1—the problem of providing rigidity for large panels has been solved by laminating porcelain enamel to any one of several core materials; with this method, flat rigid units as large as 8′ x 10′ can be fabricated to meet the architect's specifications. A 50 sq. ft. panel *(right)* is about to enter a kiln which has been heated to 1530F.

Possibilities in Porcelain Enamel

BY ROBERT A. WEAVER, JR.*

From the days of the great Chinese potters of the Sung dynasty to the present time, porcelain enamel has been in constant production as a decorative and protective finish; yet, in the process of its adaptation from a purely decorative to a functional material many of its possibilities have been lost sight of. The decorative aspects should be allied to, not replaced by, the durability made possible by today's enameling techniques. If this is done, an economical, adaptable, contemporary material is created which might have been made to order for architectural uses.

Porcelain enamel is a glass surface fused to a metal base. It is commercially practicable when applied to steel, cast iron, and cast steel. Recent developments have also indicated that enameling on stainless steel and aluminum is a practical possibility. Porcelain enamel is, in a very real sense of the word, a permanent finish. It is acid-, abrasion-, corrosion-, weather-, and thermal shock-resistant, possesses texture and color flexibility, is reflectant and workable as well as being an electrical insulator.

In many ways the fact that porcelain's potential is so little known, is due to the enameling industry's own lack of flexibility and resistance to new ideas. When asked to do something new, the industry has only too often answered that it could not be done in porcelain because of the nature of the material. Porcelain has always been smooth and shiny; therefore, one could only use it where a smooth, shiny material was specified. It chipped; therefore, it would probably always chip. Large size building panels could not be made because of the problem of rigidity. This situation simplified production for the porcelain enameling industry but it did not encourage the use of porcelain or eliminate its drawbacks. With the entry into the porcelain industry of some young firms with a flexible, experimental approach, a more constructive policy is now being tried.

new approach

A flexible approach means that when an architect or an engineer would use porcelain but for one undesirable factor, the industry should then develop a porcelain without that factor. If porcelain is indicated and a shiny surface prevents its use, then the industry should find a way to make

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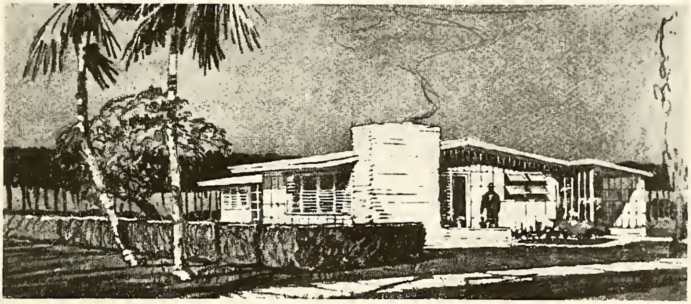
**President, Bettinger Enamel Corporation, Waltham, Massachusetts.*

it mat. If the drawback is that porcelain enamel is not a structural material, then the industry must find a way to make it a structural material. In the short time that this new policy has been put into effect, many improvements and new discoveries regarding porcelain have come into being. A mat-surfaced porcelain has already been developed; large panels can now be fabricated *(Figure 1)*; colors can be matched with consistency and exactness; and installation solutions can be worked out to suit any specific type of construction.

Installation methods, gage specification, type of core, etc., are essentially items for the architect and porcelain fabricator to work out together. Size, correct gage, and type of installation to be recommended, depend on whether a panel is to be used decoratively or functionally. A good esthetic effect is often obtained as a by-product of expert texture treatment. Today, the Porcelain Enamel Institute specifies 16-gage metal for architectural porcelain. This seems to be the same thinking which put porcelain into the doldrums, as such a rule of thumb applies only to conventional applications like gas stations. Just as an architect would not specify the same thickness of wood for shingles, clapboards, and railings, the porcelain enamel industry should not specify one thickness of metal for all architectural uses. A more appropriate type of specification would require that nothing lighter than 18-gage metal be used for panels larger than 2′ x 2′, unless the metal is laminated or rigidized in some way.

An architect has the right to expect that if he indicates on his drawings and specifications where he wants porcelain to be used, what



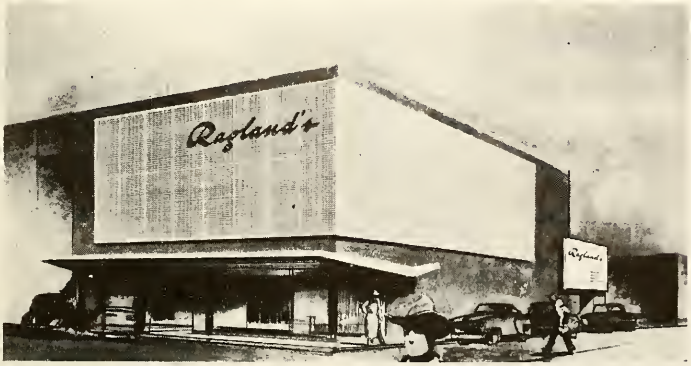


Figure 2—these spandrels *(top)* are prefabricated, porcelain enamel sandwich panels; several types of cores were used in this industrial-research structure.

Figure 3—as in this residential design *(center)*, porcelain panels should be used in combination with indigeous materials.

Figure 4—porcelain panels for a Texas commercial building *(bottom)* were perforated to eliminate distortions which would have resulted from firing.

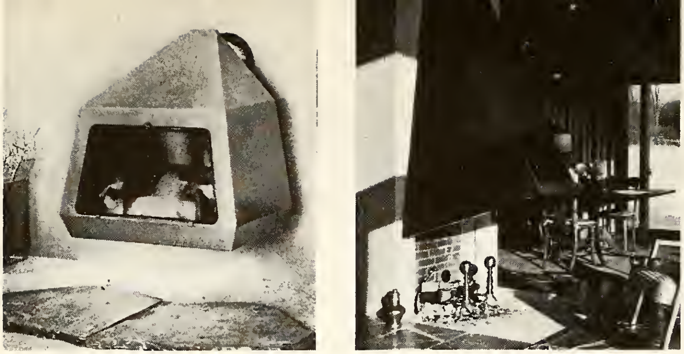
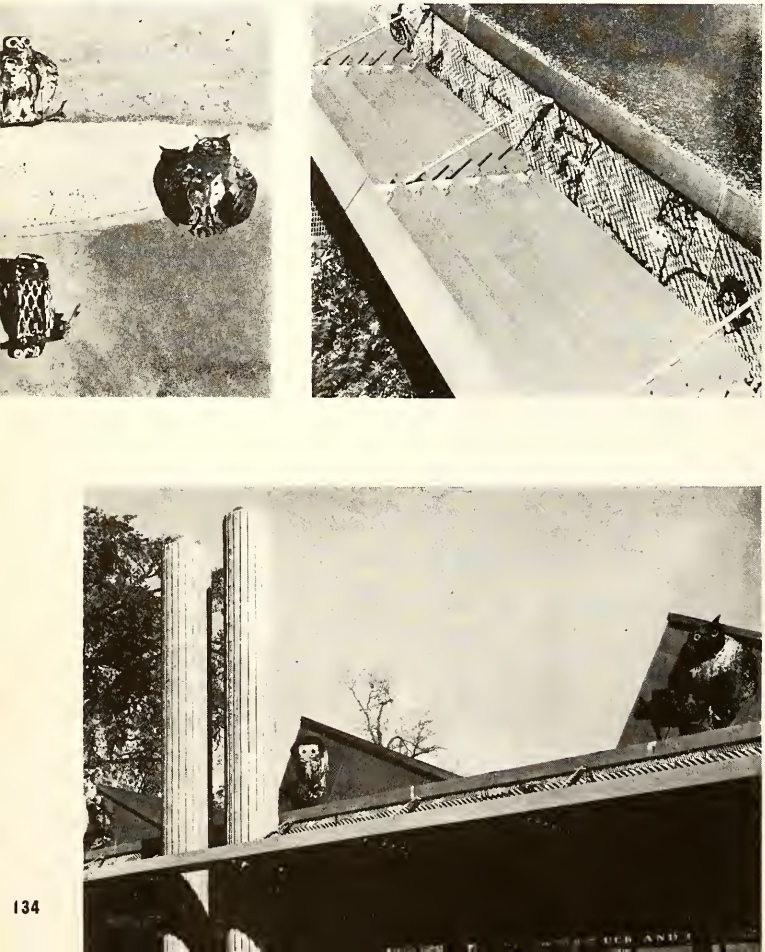


Figure 5—fireplace *(above, left)* was made for less than one half the cost of the cheapest conventional type. Success of experimental hood *(right)* suggests that porcelain enamel is suitable for many other components of the residence.

Figure 6—hand-enameled owls, corrosion and weather resistant sun louvers, and rigidized-metal frieze *(below)* are combined in a youth library patio.



qualities he wishes it to have, and what effects he wants, the fabricator can take over from there and work out the details, specification, and problems of fabrication and installation. If he is willing to search for a competent manufacturer, the architect will be able to get this type of service. Porcelain enamel companies should have—and some do—a full-time architect and engineer whose services are at the disposal of any client for just such problems as these. This solution is an excellent way to bridge the gap which has caused such trouble in the past between the enamel fabricator and the architect.

The most important recent development in the porcelain enamel field as it affects architecture is lamination. When laminated to other materials, completely flat and rigid panels as large as 8′ x 10′ can be fabricated; panels with many architectural advantages result when this material is laminated to calcium silicate tiles, honeycomb paper, or plywood cores. A sandwich-type panel, composed of porcelain enamel and a core substance, forms a complete, prefabricated curtain wall material. Larger, non-cored panels can also be made if the metal is either rigidized, fluted, corrugated, or perforated to eliminate distortions which form when a large panel is subjected to the terrific heat (1530F) needed for fabrication. Porcelain enamel can even be laminated to some structural insulating boards to form large, flat panels.

In the event that these new types of porcelain curtain wall, porcelain veneer, and large size porcelain panels are used, special attention must be given to construction. The average porcelain enameler installs a panel—frequently limited to 2′ x 2′ and 16-gage metal—on wood furring strips with interlocking clips. The industry limits itself by staying with this conventional installation, since it discourages the use of porcelain in buildings where the architect is not prepared to use wood furring because a maintenance factor might develop. Although porcelain is in every way a permanent finish, it is only as permanent as its installation. There are now special installation methods suited to structural porcelain which are absolutely permanent.

recent installations

One type of curtain wall material is made by sandwiching an insulating core between two porcelain enamel panels. Setting these composite panels in upright, slotted, or channeled sections permits quick installation at low cost and columns become a decorative part of the structure as well as the functional lock of the panel itself. Such a panel was designed by Eero Saarinen & Associates for the General Motors Technical Center in Detroit *(Figure 2)*. Colored units ranging from 2′-0″ x 4′-6″ to 4′-8″ square were mounted between steel columns and held in place by means of calk-filled aluminum extrusions; horizontal joints contain both splines and calking. The type of core to which the porcelain skins were laminated in the General Motors building—whether calcium silicate tile, plywood, or honeycomb paper—varies with the degree of heat or fire resistance needed at a given location in the building.

If properly designed, an individual porcelain house can now be built as economically as the Lustron House, which used too much porcelain improperly. The point about porcelain for private houses is that it must be used with imagination and care, otherwise the results may resemble a cross between a gas station and a bean wagon. Porcelain can be used in conjunction with local materials—like coral brick and cypress in Florida and adobe in Arizona—to soften its appearance. Also, it should be specified for places where its use is definitely called for, and even then it need not be the sole material used. The Lustron House failed esthetically because there was porcelain throughout the entire structure—even in areas where it was totally out of place. Architect Marion Manley has designed a house for Miami, Florida, which contains porcelain and local brick *(Figure 3)*. Conventional pan-type panels were used on the exterior and some porcelain, where needed, can be found in the kitchen and bathroom. By combining these two materials, Miss Manley has produced an individual, warm-looking, economical house which avoids the assembly-line look of the Lustron House while costing very little more.

Veneer panels, prevented from warping by means of perforations, were designed by Raymond Loewy Associates to renovate Ragland's Department Store in Kingsville, Texas *(Figure 4)*. The exterior load-bearing walls, a brick construction with a 150′ frontage, 80′ depth, and 50′ height, were painted a dark pink. A light pink, perforated porcelain facade was suspended 8″ away from the brickwork by means of a light steel framework bolted to the existing structure. The porcelain frontage, approximately 50′ x 20′, was composed of 3′ x 3′ panels separated by non-perforated 1″ strips in the same color. As concealed spotlights play across the surface, the perforations provide textural interest and contrast as the deeper red of the brick appears through the holes. In this case, the textural interest developed from the function of the material, as the perforations were originally intended only to eliminate distortions in firing. This simple renovation gave an up-to-date, attractive appearance to an old building while involving no exterior rebuilding or added maintenance factors.

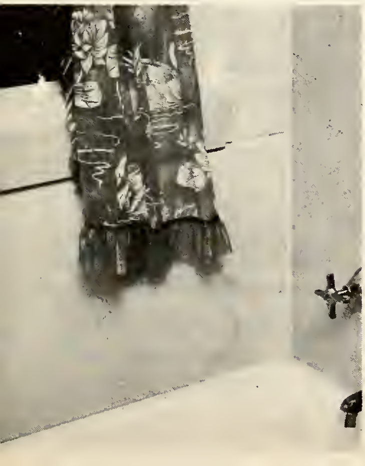
A most successful way to provide a permanent exterior surface is the method used for the Biscayne and Seagull Hotels in Miami. The architects wished to use porcelain as a protective veneer on parts of these buildings, and, at the same time, wanted to avoid the danger of maintenance problems arising from the hot, humid, Floridian air collecting behind a facade-type veneer. Pan-type units, each specially treated to obtain a rough inside surface, were half filled with a lightweight cement and stacked while drying to provide a flat, inside backing or core. The face of the building was prepared with a conventional cement and the pans set into it. The cement core of the pan formed a bond with the face of the building and a permanent, maintenance-free installation was achieved.

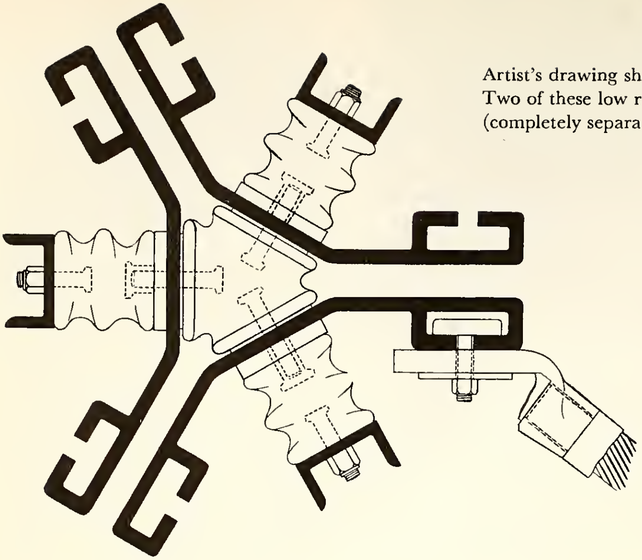
When Carl Koch designed his Acorn Houses, a housing project in Concord, Massachusetts, he wanted to include fireplaces; however, the budget did not allow for even the cheapest conventional ones. Enthusiastic architect-manufacturer collaboration produced a coniform porcelain fireplace which could be stood on legs or suspended from a wall *(Figure 5)*. It needed only a flue as preparation for its installation and could be mounted quickly by screwing it into place. These units were made in three colors—black, gray, and red—and cost $89 each, less than half the cost of the cheapest conventional fireplace. An experimental porcelain enamel fireplace hood installed in a New England residence also proved a practical interior use of this material *(Figure 5)*. Porcelain window sills and stools were designed for a high school in Weston, Massachusetts. After the installation problems were solved for this one structure, subsequent use of porcelain sills and stools in other schools and in office buildings became a simple matter. Experimentation is now going on with porcelain enameled window frames.

At the Fitchburg Youth Library in Massachusetts, porcelain was specified by Architect Koch for the frieze around the top of the building, for the owls perched on the roof, and for the sun louvers in the patio *(Figure 6)*. The panels for the frieze are 20-gage, rigidized steel and are hand-enameled in white, yellow, two shades of blue, rust, and black. They are bolted together and to the face of the building, with an air space at the back. The 3′-high owls were individually designed by Connecticut sculptor William Talbot; before being fired they were enameled by Gyorgy Kepes, Professor of Visual Design at M.I.T. Top and bottom flanges of the sun louvers are bent slightly more than 90 degrees to provide smoothness and rigidity. There are no side flanges; the louvers are supported by metal clips spot-welded to the sides and bolted to wood outriggers projecting from the face of the building.

These sun louvers are only an indication of the many architectural products which can be efficiently manufactured in porcelain enamel, if both architect and fabricator take a dynamic view of its possibilities. There is a great need for a permanent, corrosion-resistant, maintenance-free material for the component parts of a building, and there is every indication that porcelain enamel is it. The enameling industry of today is essentially a young, growing one which has hardly scratched the surface of its potential.

Figure 7—the installation of prefabricated, porcelain window stools and large, porcelain wall panels in bathrooms reduces both erection and maintenance costs.





Artist's drawing shows end view of extruded aluminum sector bus. Two of these low reactance buses (completely separated electrically) serve building.

ALUMINUM, THE CHALLENGER

Last spring, The Aluminum Association reported that the primary production of 95 companies for January 1954 was 232,493,207 lb—an increase of 52,703,012 lb over January 1953. That a sharply increasing amount of this metal (sheet and plate; foil; extruded products; tube, rod, and bar; wire and cable; forgings; and castings) is finding its way into architectural applications there can be no question. In its new office building in Pittsburgh, the Aluminum Company of America has shown the almost infinite ways that aluminum can be incorporated in the design of a modern skyscraper. In addition to the now famous aluminum-panel exterior of that building (*page 37*), this lightweight metal was used for the ceilings, lath for the sprayed-perlite backup, lighting fixtures, windows, conductors, rigid conduit, sector busses, busbars, cables and terminals, cooling towers, 60 percent of the plumbing, valves, and so on. Though some instances may have been a luxurious use of the metal, the potential of future aluminum reduction, after government needs are met, will certainly provide an abundant amount for all types of installations. Sales of aluminum windows in 1953 increased 34 percent over sales in the previous year a survey of the Aluminum Window Manufacturers Association revealed. Although the greatest increase was registered in the sale of commercial-type windows, shipments of residential-type aluminum windows rose from 1,016,000 units to 1,263,000 units over the same period, an increase of 24 percent. (*For the proper selection and detailing of aluminum windows, consider L. M. Dunn's article on page 137.*) The boom in aluminum window use was attributed to the lifting of government controls during mid-1953, coupled with increased demand, lower prices, and larger production. There is evidence of a trend to metal roofs, and due to inherent characteristics of aluminum such as light weight, corrosion resistance, reflectivity, workability, and moderate cost, this material will no doubt make a larger dent in the $2 billion annual roofing market.

Aluminum Windows—Selection and Detailing

BY L. M. DUNN*

The Technical Committee of the Aluminum Window Manufacturers Association is the first sash group to establish specifications based on performance standards. These specifications are available on request from the Association, 74 Trinity Place, New York, N.Y.

physical characteristics

When determining the proper gage for an aluminum window, one must consider its type, function, and size, as well as whether it is to be fabricated of solid or tubular sections. In general, lighter gages from .050″ to .125″ are specified for windows that are to be installed in residences or low-cost housing projects, while .062″ to .188″ gages are found to be more suitable for industrial, commercial, and monumental windows in factories, office buildings, banks, etc. A sill member should never be of lighter gage than the accompanying window frame, as it will usually be subject to harder use; in commercial buildings, for example, maintenance men have to stand on them in order to clean the glazing. Sill gage should never be less than .062″ and for windows of higher specification the thickness should be .078″, .094″, or more.

All aluminum windows should be able to pass concentrated and uniform load requirements (the conditions of these tests have been set forth by the A.W.M.A.'s Technical Committee) that are in proportion to the duties they are to perform (*Figure 1*). A smaller window of less strength should never be installed in place of a window of higher specification (regardless of the fact that the opening may be small enough to enable a window of lower specification to pass the required performance test). Such precaution will insure that units passing the same specifications for a specific window type will be used throughout a building, as well as accommodating the largest opening.

When properly performed, either mechanical joining or welding is satisfactory for aluminum windows. If two sections overlap, mechanical joining can be effectively accomplished. For abutting sections, welding or mechanical joining may be used. If gas welding is chosen, it is important that the flux be removed after the welding process is completed, otherwise, the residue may subsequently act as a corrosive substance. Although inert arc-welding cannot be used for inaccessible locations, this method and also flash welding present no residue problem. In any event, it will usually be less expensive to use the method preferred by the individual manufacturer for his own standard windows.

Finishes tend to fall into four basic types. Although there are variations of these, the architect will usually be able to keep his costs lower if he specifies one of the following:

(1) *Mill finish* — a natural finish, the least expensive of all.

(2) *Satin finish* — produced by: (a) etching in caustic; (b) belt polishing; (c) rubbing with emery cloth or steel wool.

(3) *Bright finish*—produced by buffing.

(4) *Alumilite finish* — an electrolytic type of finish developed by the Aluminum Company of America. In effect, this process provides a much thicker and more protective oxide coating than is naturally present on the aluminum. It provides an excellent appearance and can be specified for any one of the three finishes above.

Whichever finish is selected, it should be covered by a temporary protective coating, such as lacquer, to shield the window surfaces until installation has been completed.

Aluminum windows can have different colors, by introducing pigments in conjunction with the Alumilite process. In some applications, the actual alloying constituent of the metal is used to pigment the oxide coating, providing a pleasing gun-metal shade. Most other colors, however, are more suitable for interior use, as 10 years is probably the maximum service life that can be expected of colors exposed to the elements, but these colors will hold up indefinitely for interior use. Although exact color match with the Alumilite treatment is not always practical on a commercial basis, reasonably satisfactory matches may be obtained for all practical purposes. Additional data is available on color for special requirements; it is advisable, however, to consult with a prime-metal producer before preparing the final color specifications.

Protective treatments, factory applied, are a requirement of aluminum windows, mainly for appearance's sake. For protection during construction, a clear, water-white, methacrylate-lacquer, resistant to alkaline mortar and plaster, is recommended. A coating applied to an aluminum surface must be able to withstand the action of lime mortar for a period of at least one month in an atmosphere of 100 percent relative humidity at room temperature; the coating used shall also be a type to which glazing compound will adhere. Before application, the manufacturer must remove all fabrication compounds, dirt accumulations, and steel-wool fibers deposited by abrasion cleaning.

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* *Chairman, Technical Committee, Aluminum Window Manufacturers Association*

Anodizing the aluminum before lacquering will permit easier maintenance, when it is desired to preserve the appearance of windows. The finish will add somewhat to the total cost—the increase will vary from producer to producer, depending on the facilities available, and the particular job requirements.

Hardware used to control and lock ventilating units must be well constructed, to withstand the intended operation and to resist loads normally applied to it. In addition to having long life under repeated operation and being resilient to twisting, shock, and abusive treatment, the basic hardware material should not cause the aluminum to corrode; if it does, it must be treated so as to render it passive. Nonmagnetic stainless steel and "white bronze" are strong, durable materials which have demonstrated their suitability for hardware components. A few other bronzes may also be used after being heavily chrome-plated and insulated from direct contact with the aluminum window surfaces. Zinc is widely accepted for die-cast hardware, and plastics may be used to advantage.

Because of their strength, durability, economy, and attractive appearance, aluminum alloys are enjoying a rapid acceptance as aluminum window hardware. When they are specified, caution must be taken to avoid a possible galling or seizing which could result from direct aluminum-to-aluminum contact. This condition may be prevented in the design stage by providing inserts, bushings, and similar components of stainless steel, plastic, oilite bronze, or other suitable material.

Performance specifications, including standard sizes, have been developed by the A.W.M.A. Technical Committee for the use of the entire industry. These specifications are based on performance requirements rather than specifically designated physical characteristics. To establish the tests now used by the independent Pittsburgh Testing Laboratory, windows were placed under actual installation conditions and the consideration of weather-tight conditions was observed at all times. (*Figures 2, 3, and 4*).

performance factors

Air-infiltration resistance of an aluminum window varies by window type, and whether the window is mass-produced or custom-made. After the required resistance has been determined for a building, the window type will be indicated. The standard measurement of air infiltration is in terms of cubic feet per minute, per lineal foot of crack length, when a window is adjusted for normal operation and subjected to a static air pressure equal to the pressure exerted by wind at a velocity of 25 mph.

If an architect desires specific knowledge regarding the air-infiltration characteristics of a particular window, he should ask the manufacturer for copies of tests made on a window identical in construction with the window to be furnished. The tests should be performed by a recognized, independent laboratory and should prove that air infiltration does not exceed the maximum limit of the specifications. If mass-produced windows are considered, the tested model should be a production-line window. The Technical Committee has found that a performance test is far superior to feeler-gage tests used to measure the size of a crack between sash and frame. Performance counts first.

It is generally considered that sliding aluminum windows will give better service, if all contact points between sliding sash and frame are weatherstripped. Not only does weatherstripping give excellent air-infiltration control, it also permits the sash to slide more freely in the frame. The recommended specification reads "there shall be no aluminum-to-aluminum contact between window members that are required to move relative to one another and at the same time remain in contact." The nature of the window design will usually determine the location of the weatherstripping. For double-hung windows, weatherstripping is placed on the lower rail of the bottom sash; or, if placed on the sill, it must be properly protected to prevent damage by window washers.

Satisfactory weatherstripping should:

(1) Control air infiltration.

(2) Withstand external atmospheric conditions.

(3) Hold up mechanically under use.

(4) Resist corrosion.

(5) Resist galvanic action.

(6) Be easily replaceable.

(7) Keep dirt accumulation to a minimum.

(8) Be very durable in relation to sash material.

Stainless-steel, Monel-metal, felt, and plastic weatherstripping are often used to accomplish these objectives.

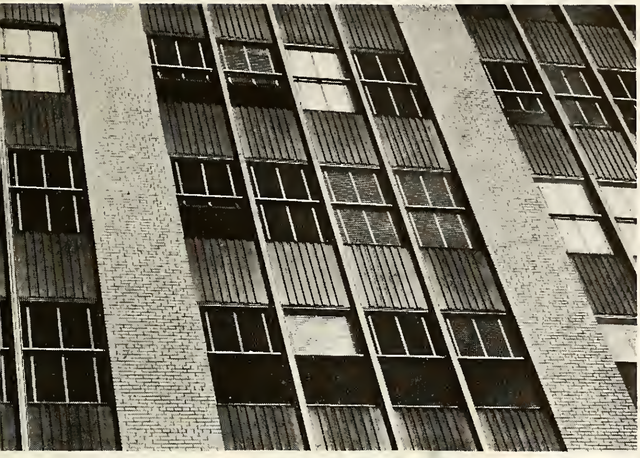
In the case of projected, casement, and awning windows, where the hardware normally forces a tight closure and where no sliding action exists, metal-to-metal contact can be satisfactory without weatherstripping.

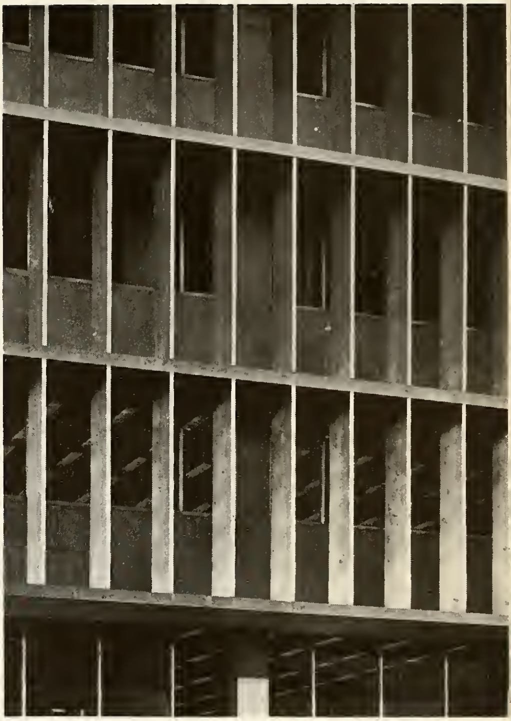
Given only nominal maintenance, the life of aluminum windows under normal circumstances would be expected to equal that of the buildings in which they are installed; no painting is required. This condition obtains, of course, only if the windows are properly designed, fabricated, and installed. Such a period of service may not always have been considered possible; however, if a window today displays the Quality Approved Seal of the A.W.M.A., architect and client can be assured they are obtaining a lasting building product.

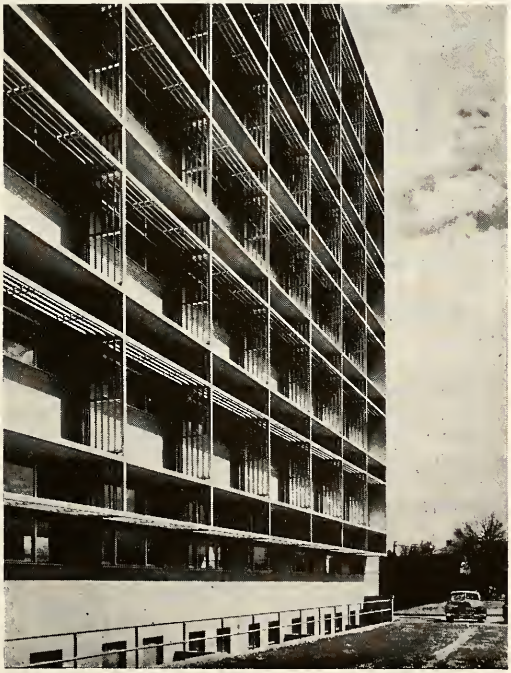
Aluminum windows can serve in any climate in which normal atmosphere exists. This would include coastal, inland, wet, dry, hot, cold, city, rural, and industrial areas. The 63S alloy, generally employed for the extruded sections of windows, contains sufficient magnesium and silicon to impart the strength required and at the same time is an alloy which can be extruded at high speed for economic advantages. This alloy has a natural silvery appearance, provides an excellent basis for any protective or decorative coating, and has a high inherent resistance to atmospheric weathering.

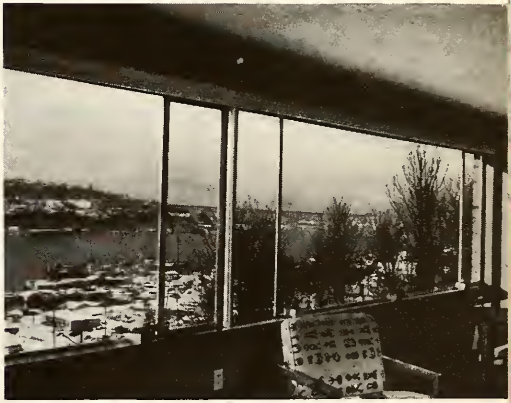
Aluminum-alloy windows have been used for the past 20 years in all types of natural atmospheres, including a wide variety of industrial and seacoast atmospheres (*Figure 6*). Based on this experience, aluminum

Year round air-conditioning required fixed aluminum sash (right) *in Pan-American Life Insurance Building, New Orleans; Architects: Skidmore, Owings & Merrill; Claude E. Hooton, Associate. Detail of 100 Park Avenue, New York* (below), *shows double-hung, aluminum sash; Architects: Kahn & Jacobs.*
Photo: Torkel Korling
Photo: F. S. Lincoln (*courtesy of Alcoa*)

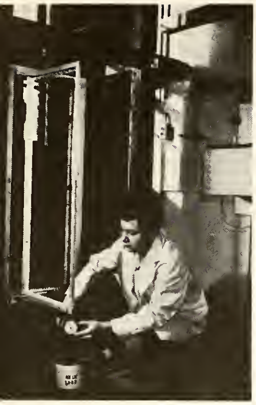








Aluminum fixed-sash and casement windows (above) *in Lakeview Boulevard Apartments, Seattle; Architects: Chiarelli & Kirk. Extruded, double-hung aluminum sash* (left) *at Georgia Baptist Hospital, Atlanta; Architects-Engineers: Stevens & Wilkinson.*
Photos: Dearborn-Massar and F. S. Lincoln



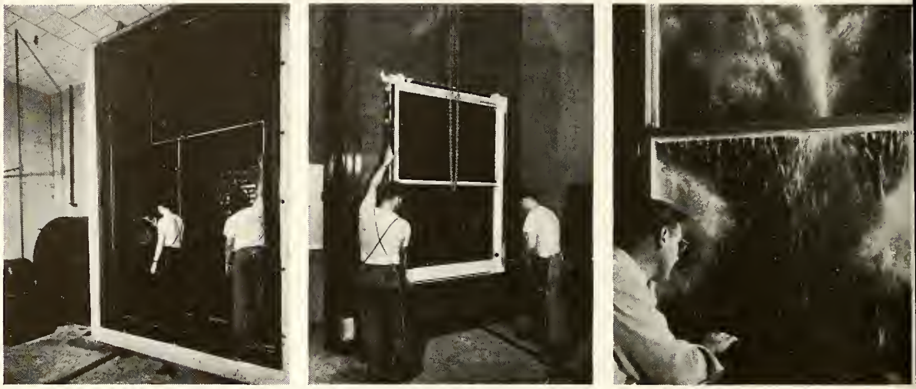


Figure 1—standard performance test on a residential casement window (left). *A concentrated load of 45 lbs. positioned as shown must not force the window beyond norms established for vertical deflection by the Technical Committee.*

Figures 2, 3, and 4—testing facilities of an individual Association member (below). *Double-testing chamber* (left) *contains blower vent and water pipe to check air and water infiltration. Installation of an aluminum window in air-pressure test chamber* (center). *Testing equipment can play 500 gpm of water on a window* (right).

Photos: courtesy of The Adams & Westlake Co.

windows may be expected to have adequate life in most industrial environments. As a rule of thumb, if a human being can work comfortably in an industrial atmosphere, aluminum windows will serve satisfactorily.

According to F. L. LaQue, chairman of the Advisory Committee on Corrosion, of the A.S.T.M., there are three basic classes of permanence which can be used as criteria in specifying aluminum windows for factories:

Class I: The metal will perform satisfactorily regardless of the industrial atmosphere.

Class II: The metal will partially resist the industrial atmosphere; windows might not last the life of the plant. Relatively speaking, these would still be considered desirable if they outlasted other types of sash under the same conditions.

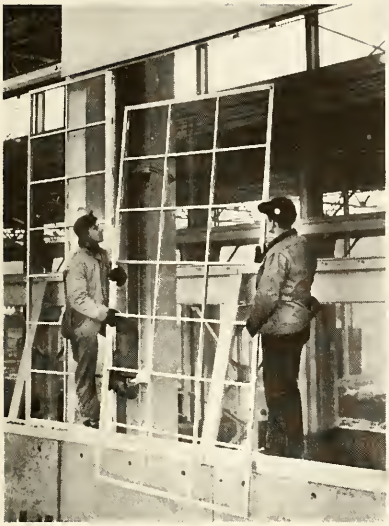
Class III: The metal will not resist the atmospheric conditions of the plant.

Architects and engineers designing plants with unique atmospheric conditions would be well advised to consult a prime-metal producer concerning the expected performance of aluminum windows on that specific job. Reference to charts on the reaction of aluminum to chemicals ordinarily considered harmful is not always a fair solution to this type of problem. It is not necessarily logical to presume that aluminum windows should not be specified, if the harmful chemicals are present only as atmospheric vapors in dilute concentrations.

Galvanic action in terms of the corrosion resistance of a material cannot be expressed quantitatively; it is only a relative term. No construction material is entirely resistant to all conditions to which it might be continually exposed. It should only be compared with other materials under similar conditions.

Unlike many other metals, aluminum has the ability to form a thin, adherent film of hard oxide, instantaneously, on freshly exposed surfaces. As this film is extremely protective, it retards oxidation and generally eliminates the need for paint maintenance. Except for the possible over-all corrosion caused by highly contaminated atmospheres, such as found around chemical plants, the only corrosive actions of any concern to aluminum windows are: (1) galvanic attack excited by nonaluminum metals; (2) drainage of salts from nonaluminum metals over aluminum windows; (3) poultice attack which aluminum and other metals suffer when held for extended periods in intimate contact with absorptive materials.

Galvanic attack is not as serious a problem in atmospheric exposures as when the dissimilar metal couples are fully immersed in a corrosive liquid. Consequently, galvanic corrosion involved in window installations can be easily controlled by the choice of dissimilar metal and the design and use of protective measures. Where practicable the dissimilar alloy can be made from another corrosion-resistant aluminum alloy. Otherwise, the most compatible nonaluminum metal possessing the physical characteristics needed should be selected. Materials that will in general perform well with aluminum are: nonmagnetic stainless steel, heavily galvanized steel, and zinc. Components of copper or nickel alloys can be used under specific conditions. In atmospheric service, galvanic attack is apt to be



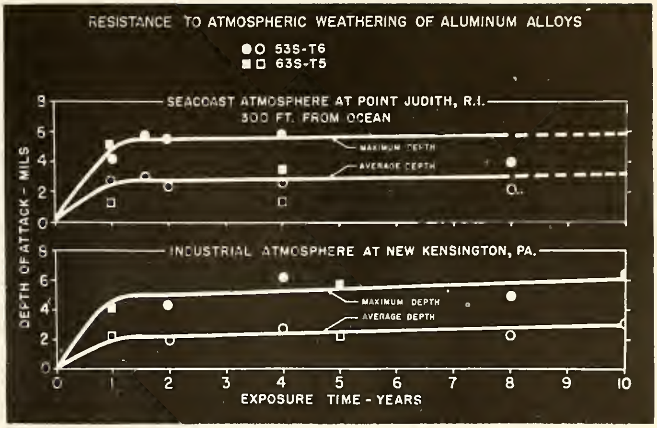


Figure 5—relatively large aluminum windows can be installed with ease (left). *Man at left, however, demonstrates what should not be done. To preserve accuracy of precision construction, a workman's weight should be supported by a ladder rather than by muntins or sash.*

Figure 6—aluminum alloy corrosion chart (above)

confined to the faying surfaces of the joints. This type of corrosion is minimized or prevented by providing weathertight joints between the components, either by mechanical tightness, or mechanical tightness plus the use of such protective coatings as lacquer, zinc chromate, bituminous paint, nonconductive and nonabsorptive gaskets, or mastic seam compounds. Locating the joints to provide free drainage of moisture away from the couples, is essential.

The use of water-absorptive building materials (such as wood or insulation board) between aluminum and the dissimilar metals (such as steel) can result in direct galvanic corrosion, if the absorptive materials remain wet or damp. An electrical contact between dissimilar metals could easily be effected by a metal fastener; however, no galvanic attack could occur if the metal parts were fully insulated from one another. Where this cannot be effected, the use of a uniform layer of water-resistant mastic between the aluminum and nonmetallic member will generally prevent galvanic attack.

Corrosion of aluminum windows can also be caused by wash from dissimilar metals, notably of copper and nickel. Such drainage contains salts of copper and nickel which plate out over the aluminum surface and create tiny galvanic cells between the aluminum and the copper or nickel particles. Iron salts are considerably less harmful in this respect. It is important, therefore, to prevent drainage or drippage from flashing, gutters, valleys, or ornaments of copper or nickel alloys from coming in contact with aluminum windows. This type of corrosion can be prevented by maintaining a paint coating over the dissimilar metal parts.

Poultice attack, as the name implies, may result from extended contact of aluminum or any other metal with a water-absorptive material. These materials hold moisture against the metal surface for longer periods of time than the freely exposed surfaces; they also screen oxygen away from local spots of the metal. This situation creates small galvanic cells between spots having different amounts of oxygen or moisture present. The absorptive material itself does not have to be corrosive and certain types of products create greater poultice attack than others. Poultice attack on aluminum windows might be caused by wood, insulation board, or poorly impregnated building paper, if these were to remain continually wet and in contact with the aluminum. Poultice attack is best prevented by not allowing construction materials to become wet. One successful precautionary measure is to make nonmetallic construction materials water-resistant by painting; another measure is to seal out moisture from a joint by means of a mastic calking compound.

Where aluminum windows come in contact with masonry, the prime consideration is to be sure that a close fit exists between frame and masonry. It should be determined whether the frame is going to set behind masonry or butt against the masonry reveal. When cement block is used, special attention should be given to specification and application details. Where possible, it is advantageous to use cement blocks that are made especially to receive windows. An architect should inspect the

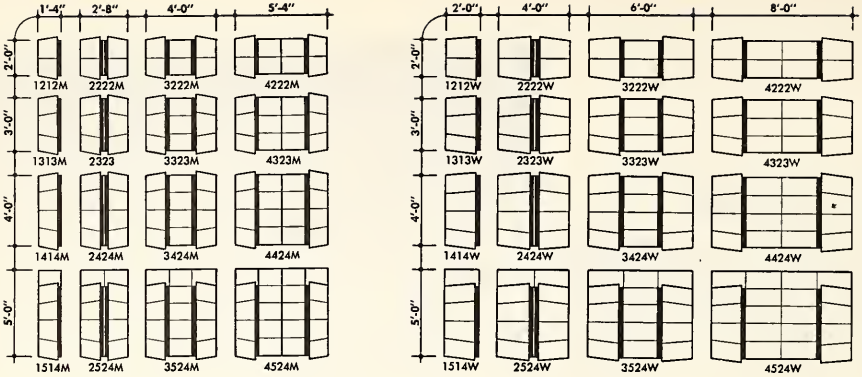
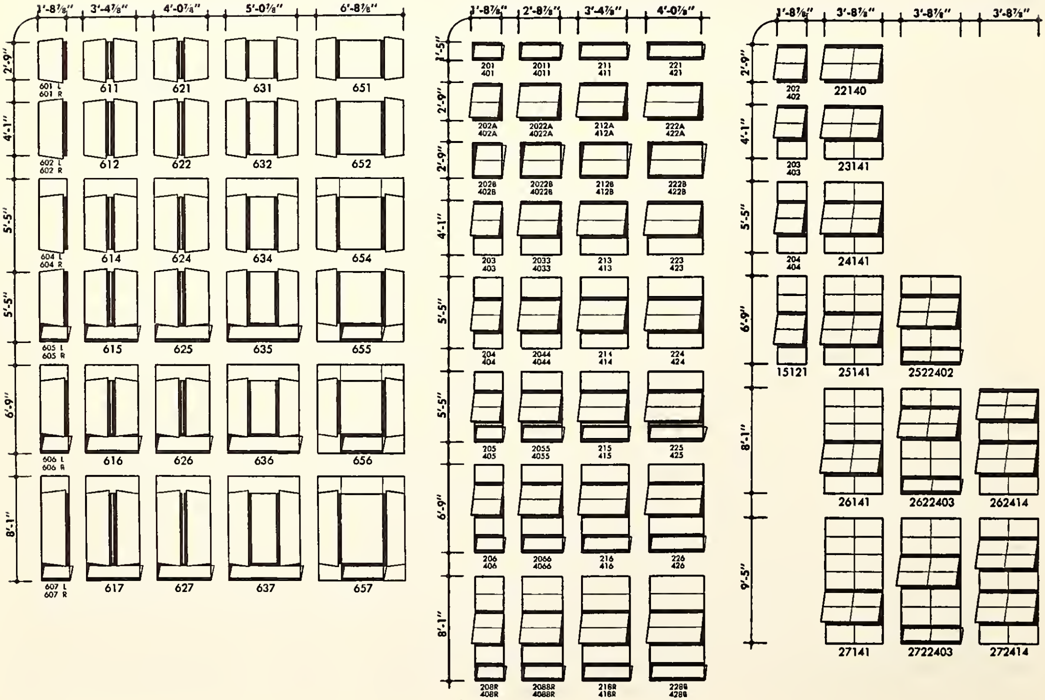


Figure 7—modular standards for residential casement windows (above left); *larger units are known as "western modular"* (above right). *Dimensions of standard casement windows for commercial and monumental buildings* (below left); *standard projected windows—vertical and horizontal muntin types—for residential, commercial, and monumental buildings* (below center and right).



manufacturer's recommendations for installation and anchorage to insure that adequate calking is provided. Every effort should be made to eliminate any crevice which might allow water to collect around the frame.

installation factors

Each aluminum window manufacturer will normally show in his own literature the best method of anchoring his windows to structural frames; his representative should be consulted in the event that special designs are used. To insure proper anchorage, the following fundamental check points should be kept in mind:

(1) Anchorage must hold the window rigid.

(2) Strong anchors are required for jambs of commercial windows as they must satisfy the needs of the window cleaner.

(3) Windows must be supported securely at sill in order to withstand normal use of window cleaner.

(4) Additional anchors are normally required at mullions.

(5) Anchors should be manufactured and installed to obviate any staining on the trim or window surfaces.

(6) All anchoring devices used in the erection of aluminum windows must be of aluminum, nonmagnetic stainless steel, or other corrosion resistant materials compatible with aluminum. Steel anchors may be used, provided that they are adequately protected by paint.

Many aluminum window manufacturers offer attachable fins in residential construction which serve as anchoring devices in themselves. The window is in effect built into the masonry or fastened directly to the rough woodwork.

Because of aluminum's lightness relatively large individual windows can be installed with ease (*Figure 5*). Four to six smaller windows can be handled as one unit and two men can speedily lift four to six windows mullioned together. But it should be remembered that large assemblies made up of individual units in the factory are feasible only up to a certain point, because of the controlling factor of transportation. In such instances, assembly at the site provides a simpler solution.

A mastic type of glazing compound that does not require painting should be specified. As aluminum-colored mastic alone is insufficient precaution, a compound should be labelled, without qualification, that it does *not* need painting. A glazing compound should remain elastic enough to perform properly when subjected to the rigors of atmospheric environments. Mastic-type compounds are advantageous, as they permit a broken light to be replaced easily, as opposed to those glazing materials which become hard and brittle. Aluminum windows can be prepared either for inside or outside glazing. Interior glazing is advantageous for light curtain-wall construction, as the need for exterior scaffolding is usually eliminated.

Aluminum windows require little maintenance to preserve their appearance and efficient operation. Their care consists of merely washing the sash, along with the glass; the frequency of washing depending on the locality of the installation. Caustic or acid cleaners should not be used. There are many solutions marketed today that are satisfactory for washing both glazing and sash. The aluminum surfaces then should be dried, along with the glass. Periodic cleaning contributes to preservation of appearance.

If it becomes desirable to brighten aluminum windows that have become dull from dirt and smoke, they should be scoured with a good grade of kitchen cleanser. After being rinsed and dried, they should be given a coat of liquid wax. In severe cases, it may be necessary to clean windows with fine steel wool well lubricated with liquid wax; excess dirt and wax can be removed with a clean cloth. Such a process will make the windows gleam, keep brighter longer, and make maintenance easier.

design factors

To reduce unnecessary fabrication costs through design and stock sizes is a problem which should be worked out with the individual manufacturer concerned. If a manufacturer's representative is consulted at an early stage, he can usually make minor suggestions for proper application, anchoring, trim, and glazing, which can result in substantial savings for the owner. Some general factors which assist an architect in maintaining minimum costs are:

(1) Maximum use of one type and size of window throughout a building.

(2) Uniform design of windows.

(3) Only minor adjustments, at most, on a standard design recommended by a manufacturer.

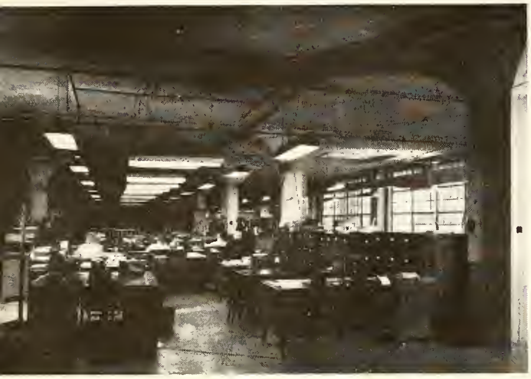
(4) Stock designs.

Although there is a tendency on the part of some architects to consider that stock units may possibly be inferior, it should be remembered that they too are required to meet the same tests for performance as custom windows when so specified.

The A.W.M.A. published its first modular standards in 1952 for residential, commercial, and monumental applications in casement and projected-type windows. A number of members already offer modular double-hung windows. Groupings for modular double-hung and awning-type windows are now under consideration by the Committee. In addition to modular standards for residential windows, "western modular" sizes are available for the benefit of those who prefer larger units (*Figure 7*). Standard sizes have also been established for basement windows. Most manufacturers offer "picture" windows not only in a wide range of heights and widths but also accommodating either ¼″ plate glass or double-glazing up to one inch.

Aluminium windows can be specified for any type of curtain wall. When standard windows are not suited for the required conditions, it is usually not difficult for a manufacturer to alter his fabrication processes to meet the specific design requirement. For example, it is relatively easy to use a frame member from an inexpensive die to suit a particular condition; an adapter can be readily applied to standard windows to serve the same purpose. A proper window design also utilizes the lightness of aluminium for a saving in labor.

Aluminum Ceiling Combined with Air Conditioning



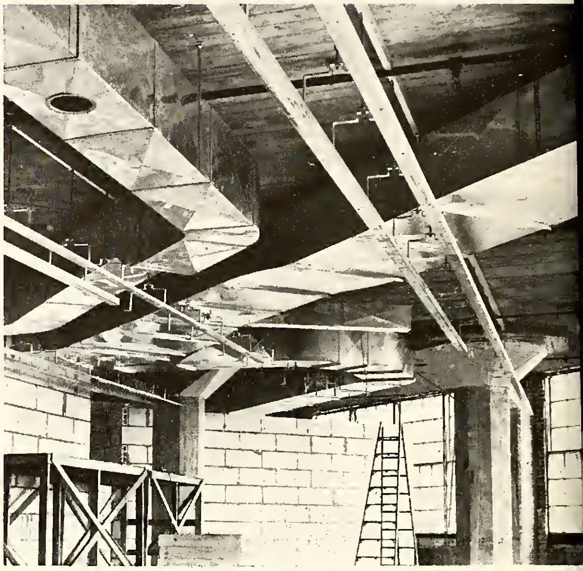


Figure 1, above—this reinforced concrete structure was once used as an assembly plant by an automobile manufacturer. In this photo, taken before remodeling, it temporarily houses a general sales office with its gloomy maze of filing cases, desks, and electrical wiring equipment.

Figure 2, right—aluminum ducts being hung from existing concrete slab ceiling. Pairs of channels which will support light troughs are 7′-0″ on center.

Perforated aluminum ceiling panels combined with one type of acoustical material or another have been successfully installed in many parts of the country for a number of years. In Louisville, Kentucky, Architects Stratton O. Hammon and Neal O. Hammon have now combined a perforated, corrugated aluminum ceiling with an air-conditioning system in the general sales offices of the Reynolds Metals Company. Their system, conceived by Neal O. Hammon, forces year-round conditioned air through the perforated ceiling to achieve the following advantages: 1) increased evenness of air distribution; 2) elimination of need and appearance of diffusing registers; and 3) reduction of cost.

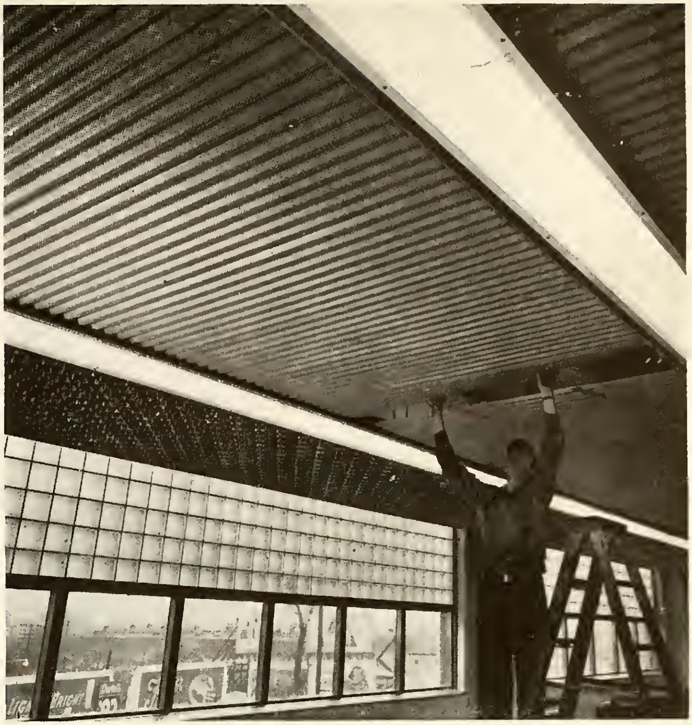
The architectural program for this structure required that the architects remodel an existing five-story industrial building which had previously been used as an assembly plant by an automobile manufacturer. On each of the five levels, the architects were given a space of 200′ x 100′. Five percent of this area was to be enclosed by ceiling type partitions; the remaining 95 percent to be divided by relatively low 4′-6″ partitions to separate the differing activities of the office personnel.

Although this corrugated aluminum material was only manufactured by Reynolds to provide an inexpensive and permanent acoustical ceiling for the trade, its design made it readily adaptable for the passage of air. To control the temperature of these offices, conditioned air is distributed through aluminum ducts above the ceiling to selected locations and then allowed to find its way down through the perforations. In some instances, there is only one inch between the duct and the corrugated aluminum ceiling. Leaving through holes in the bottom of the ducts (see Figure 2), the air is baffled by a single piece of aluminum plate. The perforations through the ceiling, which comprise about 35 percent of the surface area, are of a diameter that causes the air to distribute itself before penetrating the ceiling. Return air registers are located in the outside wall near the floor.

While still in the design stage, critics agreed that cold air has an inclination to fall in the summertime and that such an air movement would assist the operation of this system; at the same time, they also warned that a natural tendency of hot air to rise might cause the system to fail in the wintertime. As a result of tests taken on one floor through an entire year, however, it was generally agreed that the system works perfectly. During the same testing period, an attempt was made to zone control six different sections of this 200′ x 100′ area. After a reasonable amount of adjustment, it was possible to control all sections separately and efficiently. To date, this ceiling has exhibited no tendency toward darkening as a result of small amounts of dirt and dust that may remain in the conditioned air. Should this darkening someday occur, the architects state that the aluminum ceiling can be easily lifted out of place, wiped off with a damp cloth, and replaced by a janitor or unskilled laborer.

Figure 3, right—unskilled worker raises corrugated aluminum ceiling panel which can be easily removed for cleaning. Corrugations are 2½" on center and ⅞" deep; note overlap in upper right corner. For future installations, the architects recommend that 25 percent of the surface area be perforated.

Figure 4, below, right—view of sales office after remodeling; job was completed last fall. Fluorescent lamps in aluminum troughs, 9'-6" above floor, deliver 40-footcandles of illumination at desk level. Double glazing helps provide both thermal and acoustical insulation.



A layer of glass fibers, applied with mastic on the underside of the concrete slab above the aluminum ceiling, undoubtedly assists the holes to provide excellent acoustics. One unusual observation of this installation has been that better acoustics seem to obtain when the blowers are off and not forcing air through the perforations. Apparently the forward movement of the air is sufficient to reduce the acoustical efficiency of the ceiling; however, this reduction is too small to be of consequence.

The gage of the aluminum sheeting is .032; its extremely light weight, .432 pounds per square foot, made it possible to hang the entire ceiling on the light troughs (see Figure 3). Frequently in the past, when other materials were suspended between troughs, their heavier weight made it necessary to maintain a relatively small distance between lighting units. With this corrugated material, however, the architects were able to span any desired width without overloading the carrying capacity of the light troughs. Although the maximum span for this gage is about 12 feet, it was not used in excess of 7 feet in this installation.

The original building possessed a satisfactory sprinkler system which the architects wished to keep intact for reasons of economy and appearance. The perforated panels were hung under the sprinklers; in the event of a fire, they spray out as before and the water drips through the ceiling with effective results.

At the exterior wall, light-directing glass blocks extend past the new ceiling to the existing concrete. Natural light entering the space between the ceiling and the floor above is reflected back to the working area through the aluminum grille in the ceiling near the window. The structural aluminum framework which contains sash for six windows weighs but 75 pounds. Glass block units were laid directly above these multiple windows without the use of additional steel.

CONCRETE AND PLASTER

Speaking before the Concrete Industry Board in New York recently, Prof. Gustave Magnel of Ghent, Belgium, international authority on prestressed concrete construction, offered the following thoughts on the production of prestressed concrete as a building material. "Why has prestressed concrete not become (generally) a normal thing in the United States? I do not say in the North American continent, because what I'm going to say does not apply to Canada where they are making headway now. One of the main reasons is your building codes. But there is another reason and that is that you are very poor concrete makers. In this country, you have a special religion, with a special slogan. That religion's slogan is 'Save Labor.' Save labor and, therefore, you make *soup* when you make concrete . . . When you construct the average building in reinforced concrete, why should you make more than 3000 psi concrete? It is sufficiently good . . . But when you come to prestressing concrete—that is to make beams and bridges using only one-half the concrete and using only one-fifth the steel that you do in conventional reinforced concrete—don't you feel that it is wiser to make better quality materials? That is the great issue that one must fight out in this country . . . Americans are saving labor up to increasing production costs . . . Three days ago, however, in Tacoma . . . I saw a prestressed-concrete plant. I saw a plant doing pretension work, as you call it—beams up to 50 and even 60 ft span. The engineers working in this plant were ones who had come to Belgium to see my laboratory; who saw the field work we were doing; and who believed that it was possible in this country. They made no-slump concrete in their plant and they made concrete with a water-cement factor of .32, which I have checked. Their beams were *perfect* as regards external aspects and quality. They produced concrete which gave on cubes—I must admit on cubes—7000 psi concrete after three days. I asked them 'Does that cost you a lot of money?' 'Well, no,' they answered, 'why should it cost more than making poor concrete?' But they used the proper tools for making it."

For a good round-up of prestressed concrete today, here and abroad, read J. J. Closner and Cedric Stainer's discussion (*page 69*); for a sound analysis of controlled concrete don't overlook the article by William J. McGuinness (*page 147*).

Controlled Concrete

BY WILLIAM J. McGUINNESS*

Specifications for ordinary concrete usually do not require preliminary testing of materials, inspections of mixing and placing, or a fixed water-cement ratio. The resulting concrete may or may not have sufficient strength to perform its assigned tasks. Frequently, such a material will be pervious to water filtration, subject to disintegration from freezing and thawing, and will not have durability against wear. Controlled concrete, designed to meet a predetermined strength, will possess durability, resistance to attack by frost, and resistance to the admission and passage of water. On the following pages, the author presents the design requirements, job precautions, properties, and economies in the use of controlled concrete.

Table 1—Net Water-Cement Ratios for Various Types of Construction and Exposure Conditions*

Type or location of structure	Severe or moderate climate, wide range of temperature, rain, and long freezing spells or frequent freezing and thawing					Mild climate, rain or semiarid; rarely snow or frost				
	Thin sections, gal. per sack		Moderate sections, gal. per sack		Heavy and mass sections, gal. per sack	Thin sections, gal. per sack		Moderate sections, gal. per sack		Heavy and mass sections, gal. per sack
	Reinf.	Plain	Reinf.	Plain		Reinf.	Plain	Reinf.	Plain	
A. At the water line in hydraulic or waterfront structures or portions of such structures where complete saturation or intermittent saturation is possible, but not where the structure is continuously submerged:										
In sea water	5	5½	5½	6	6	5	5½	5½	6	6
In fresh water	5½	6	6	6½	6½	5½	6	6	6½	6½
B. Portions of hydraulic or waterfront structures some distance from the water line, but subject to frequent wetting:										
By sea water	5½	6	6	6	6	5½	6½	6½	7	7
By fresh water	6	6½	6½	6½	6½	6	7	7	7½	7½
C. Ordinary exposed structures, buildings and portions of bridges not coming under above groups	6	6½	6½	7	7	6	7	7	7½	7½
D. Complete continuous submergence:										
In sea water	6	6½	6½	7	7	6	6½	6½	7	7
In fresh water	6½	7	7	7½	7½	6½	7	7	7½	7½
E. Concrete deposited through water	**	**	5½	5½	5½	**	**	5½	5½	5½
F. Pavement slabs directly on ground:										
Wearing slabs	5½	6	**	**	**	6	6½	**	**	**
Base slabs	6½	7	**	**	**	7	7½	**	**	**

G. Special case: For concrete not exposed to the weather, such as interiors of buildings and portions of structures entirely below ground, no exposure hazard is involved, and the water-cement ratio should be selected on the basis of the strength and workability requirements.

*Adapted from Table 1 of the 1940 Joint Committee "Report on Recommended Practice and Standard Specifications for Concrete and Reinforced Concrete."

**These sections not practicable for the purpose indicated.

quality

Most structural materials are manufactured to a rigid quality-specification. Steel is controlled before rolling. Wood is grade-marked according to a well-established code. The approved processes for the manufacturing of good concrete are as definite as those of any other material. The architect who specifies it can have full confidence in its ability to perform all of its assigned functions as a structural and finish material. Concrete, however, is the only material manufactured at the site, and the process is not complete until it has attained its prescribed strength in the structure. A wish for speedy job methods will often prompt the omission of the relatively simple planning and precautions that make possible a quality product. As a result, the use of "average" or "ordinary" concrete is frequent.

"Ordinary" concrete is the term usually applied to a material specified by volume relations as "1-2-4 concrete." The proportions refer to the relative volumes of cement, sand, and coarse aggregate (gravel, stone, or slag). Another approximate method of concrete specification is by the "cement factor" or number of bags of cement per cubic yard of concrete. The relation of water to cement is not always fixed, although sometimes an upper limit is established as "not more than seven and one half gallons of water per sack of cement." It is also common to specify a minimum cement factor as "not less than five bags of cement per cubic yard of concrete."

Such a concrete may have fair strength if carefully handled, placed, and cured. It is, however, frequently porous, subject to disintegration by freezing and thawing, pervious to water infiltration, and not durable against wear caused by traffic.

controlled concrete is different

Controlled concrete is scientifically designed, placed, and cured to achieve a predetermined strength (usually high) with definite characteristics of durability, resistance to attack by frost, and to the admission and passage of water. The basic determinant

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**Professor of Architecture, Pratt Institute, Brooklyn, N. Y.*

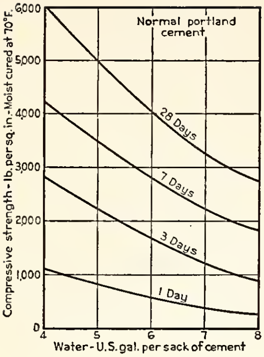


Fig. 1. Age-compressive strength relation for concrete made with normal portland cement. Strengths indicated should be obtained on average construction projects where materials are carefully controlled.

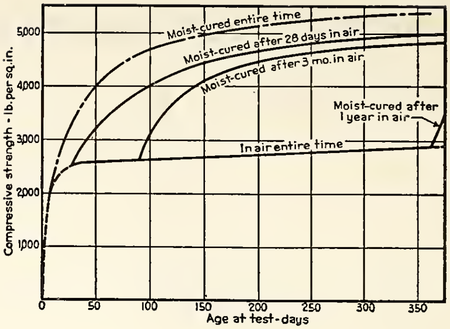


Fig. 2. Strength of concrete continues to increase as long as moisture is present to promote hydration of the cement. Note that resumption in moist-curing after a drying period also increases strength.

is the relation of water to cement. This ratio is the number of gallons of water for each 94-pound bag of cement. This sets the strength and also the durability, provided that other prescribed job procedures are followed. All materials are tested. The slump or consistency is controlled by the relative weight of aggregate with respect to the cement paste. Economy and workability are improved by varying the relative sizes of aggregates. Job procedures of placing, tamping, and curing are carefully specified. Tests for strength and slump are required. All materials are weighed before combining.

A specification for controlled concrete would include a number of general requirements. Water and aggregates must be tested for purity. Aggregates must be tested for soundness, strength, and durability. Make sieve analyses of large and small aggregates to determine the variation in sizes (grading). The grading and the relative proportion of sand to coarse aggregate are studied to achieve maximum workability, economy, and the correct slump (consistency). Using these job materials, a number of test cylinders are made to be broken in compression 28 days after casting in order to predict probable job strength. These cylinders are made with various water cement ratios in order to produce a job "curve" similar to the 28-day curve in Figure 1. From this job curve a water cement ratio is chosen for the desired strength and durability. It is usual to design the concrete for strength 15 percent higher than the engineer uses in designing the structural members in the building. During the progress of the job, slump tests are made frequently. The aggregates should be rechecked to permit adjustments if a different material is delivered. As the work progresses, test cylinders are made representing each portion of the structure. These should be tested at 28 days. Vibration and tamping are required as well as heat in winter and covering or moist curing after the concrete has been placed. Reports of tests are sent to the architect, engineer, and owner. The local building department may also require copies of them. This process obviously requires the services of a testing laboratory, and where such a laboratory is not available it will not be possible to do better than specify and use an "ordinary" concrete. An uncontrolled concrete may achieve an ultimate strength in compression of 2000 or more pounds per square inch at 28 days. With careful methods it may well turn out to be much stronger than this, but the extra strength cannot be used in the design, because without the full "control" routine including strength tests, few codes

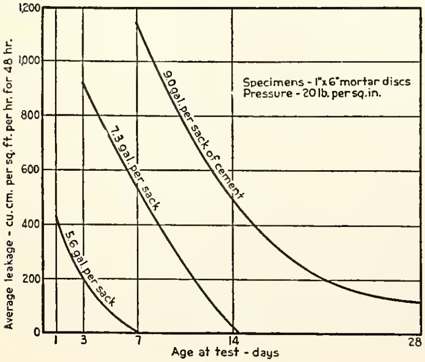
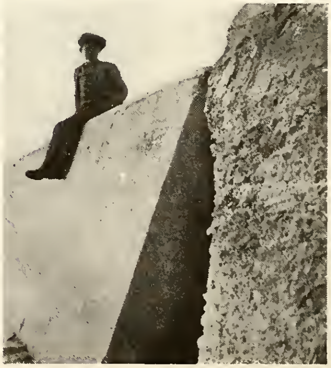


Fig. 5. Effect of water-cement ratio and curing on permeability. Note that leakage is reduced as amount of mixing water is decreased and as curing period is increased. Concrete that does not leak is made by using a small amount of water and by curing it well.

Photo at right: a lean mixture with a high water content produced the inferior breakwater shown at right. Exposed to severe weather conditions for 25 years, the section at left, which contained a richer mixture and lower water content, is still in good condition.



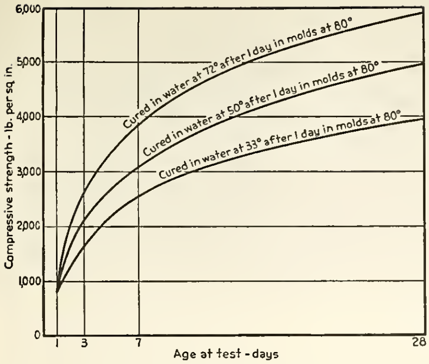


Fig. 3. The strength and other properties of concrete improve more rapidly at normal temperatures than at lower temperatures.

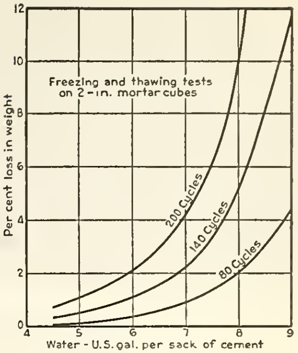


Fig. 4. Effect of water-cement ratio on durability. Note that for 2 percent loss in weight, mortar made with 8 gal. water per sack of cement withstood only 80 cycles of freezing and thawing compared to 200 cycles when the mortar was made with 6 gal.

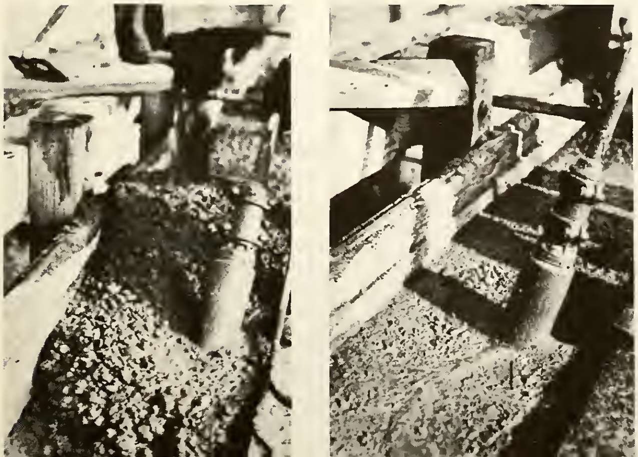
will permit more than the 2000-pound value. With control 10,000 pounds has been attained in cast stone work and 3500 pounds is quite common in structures.

Of equal importance with increased strength is the superior durability of high-strength concrete. It will not disintegrate in cold climates and it wears well as an industrial floor. Frequently, the requirements of durability will call for a lower water cement ratio than the requirements for strength. This is shown in Figure 1 and Table 1. If a low water ratio is chosen (less water per sack of cement) for durability, the resulting strength may be greater than was contemplated. The engineer will use this greater strength in his design with resulting economies. For example, let us suppose 3000-pound concrete is desired. Figure 1 shows a water cement ratio of seven and one half gallons per sack. For thin sections in an ordinary exposed structure in moderate climates ("C" in Table 1), a ratio of six gallons per sack is chosen. This water cement ratio will result in 4000 pounds per square inch (Figure 1). This is in excess of the strength contemplated and is the result of a water cement ratio chosen primarily for durability. The higher strength, however, will be utilized by the engineer in the structural design.

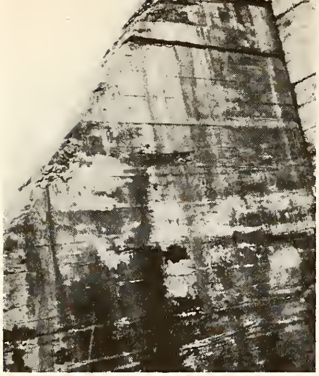
The selection of the water-cement ratio, maximum slump and maximum aggregate size, and the subsequent planning and supervision, call for the closest cooperation between the architect, engineer, testing laboratory, and ready-mix plant. When the job starts, the contractor joins this group. Prior to this event, the mix has been fully designed, including the proportioning and testing of aggregates to insure maximum workability and economy.

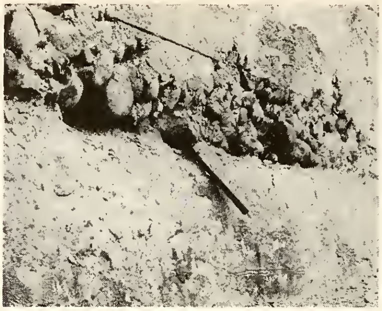
job precautions

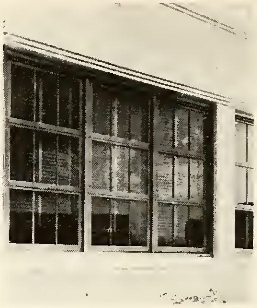
The advent of the ready-mix plant has helped immeasurably in the stabilizing of the quality of concrete arriving at the job. The balance of the manufacturing process is carried on by the job and is of equal importance with the concrete mixing. The batches must be placed promptly and carefully. Delay or careless placing methods can spoil the finished product. Water, cement, and aggregates all have different weights and will separate easily. Wet sections frequently at the top will have a different water cement ratio than was planned and will result in very weak and vulnerable concrete. This is sometimes referred to as "water gain." Gravel by itself will form a honeycombed structure with voids unfilled by cement paste. It will be porous and weak. Vibration is a great aid in the placing of concrete in the



Left: concrete has just been placed in forms and vibrator is being put to work. Right: view shows complete puddling of concrete after proper vibration.
All charts and photos, except as noted: Portland Cement Association







Left: as a result of segregation and water gain in this wing wall, the more porous concrete at top of each lift has eroded due to weathering. Better concrete at bottom of lift remains in good condition.

Center: an example of severe honeycombing due to lack of vibration.

forms, but it can be overdone and cause separation and sand streaking. An adequate temperature and the presence of moisture are essential during the setting period. Indeed, a low temperature or rapid loss of moisture will seriously retard the hardening process and cause permanent loss of strength and durability. The concrete will fall short of its design characteristics in spite of all the preliminary planning. Figures 2 and 3 are a strong argument in favor of these two precautions. They show a decided difference in strength between the best and the worst conditions if curing and temperature recommendations are not followed.

sources of information

There have been many recent advances in concrete technology to supplement and improve the standard procedures outlined briefly herein. Air entraining cements and admixtures have increased greatly the durability of concrete. The vacuum process is adaptable to special problems. Precasting gives us concrete units of factory-controlled quality.

Information can be had from a number of sources on new developments as well as basic theory and practice. The following list suggests a few such publications.

Design and Control of Concrete Mixtures. 9th Edition. Portland Cement Association.

Tentative Specifications for Ready Mixed Concrete. A.S.T.M. Designation C 94-47 T, issued 1947. American Society for Testing Materials.

Cement Dispersion and Air Entrainment. The Master Builders Company.

Exercises in the Design of Concrete Mixtures. Stanton Walker, National Ready Mixed Concrete Association.

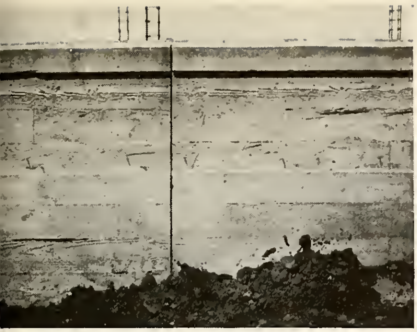
ACI Standard Recommended Practice for the Design of Concrete Mixes. ACI 613-44. American Concrete Institute.

concrete can be left exposed

It is a fact that the best concrete will not disintegrate in the coldest climates. To assure this it is necessary that the reinforcement have a minimum of 2" of cover to prevent rusting, with consequent spalling. A greater difficulty is the cracking due to volumetric changes caused by great variations in temperature. These cracks can be localized by the use of control joints, construction joints, and by the proper distribution of steel reinforcement.

Horizontal cracks are less frequent than vertical cracks. This is because concrete in compression seldom cracks. Particularly vulnerable are spandrel beams, thin and long spandrel walls, and the points at the corners of windows and doors where there is a thin section of concrete between two bulkier sections. Engineer Fred Severud has had good success in localizing vertical cracks by the use of construction joints 60 feet apart in the length of a building and designing the steel to unify the concrete in between these joints. The scheme consists of placing alternate sections of the building 60 feet in length and later completing parts in between the original sections. It is apparent that designers will set the size of each portion of the building placed in one operation. This will determine the position of the construction joints, a decision which used to be left to the contractor. Tuck and Eipel, engineers, selected 48 feet as the length for sections in the construction of the Aqueduct Race Track, and there has been no cracking between these construction joints in this fully exposed structure.

The most common causes of disintegration of concrete are freezing and thawing, and wetting and drying, which, in turn, are caused by the porosity of the concrete and the lack of soundness of the aggregates. These faults will also create a leaky material. Control can be just as successful against leakage as it is against disintegration. Figures 4 and 5 show how closely these qualities are controlled by the water cement ratio. These cycles of freezing and thawing, wetting and drying, can cause harm only when water gains entrance to holes in the concrete. The holes are caused by too much mixing water which, instead of combining with the cement, dries out and leaves a porous material. The greatest advance in achieving durability greater



Above: appearance of control joint before completion of building. Right photo on adjacent page shows the same joint after this California school was completed. Filler and paint have blended the joint with the rest of the structure.

Controlled concrete was employed throughout this apartment building. Exposed columns and aluminum covered spandrels have provided an economical, leakproof structure. Horizontal grooves in columns hide construction joints between lifts and help eliminate any appearance of deviation in the columns. Interior and exterior surfaces are free from imperfections. This unit is part of an apartment development in Forest Hills, L. I. Owner, Dwelling Managers, Inc. *Photo: Ben Schnall*

than that possible in normal concrete control has been the discovery of the principle of air entrainment by the use of admixtures.

This is a completely separate study and it does not take the place of control, but rather adds to the need for further control and tests. So effective has it been that the United States Corps of Engineers uses it wherever good durability is required. In a research paper summarizing the reasons for this decision, the following statement is made: "The profoundly beneficial effect which purposeful entrainment of regulated quantities of air has on the durability of concrete was the most important fact developed."

economy

On large jobs the cost of careful design and control will nearly always be saved by the lighter structure resulting from a stronger material. In many cases it has put concrete in a way to compete favorably with other structural systems. Housing authorities have chosen it for many of their projects. David Rose, president of Dwelling Managers, Inc., whose building is illustrated on these pages, has found it preferable to steel in some instances. His findings were based upon complete sets of structural designs and drawings for comparative systems. Patrick J. Callan has used exposed concrete with economy in the construction of small houses.

challenge

It may be a source of wonder to some that concrete has not been more confidently used for superstructure in buildings and for exterior and interior finishes. Certainly great progress is being made at present. John Hogan of the Portland Cement Association attributes the slow progress in the past to the mistaken concept of concrete as primarily a foundation material.

The use of concrete in superstructure, and particularly in exposed positions, presents a challenge that cannot be met by the same easy methods that are possible in bulk foundation work. Attention is needed for tight forms, careful shoring, careful placing, moist curing, and heat when required during winter.

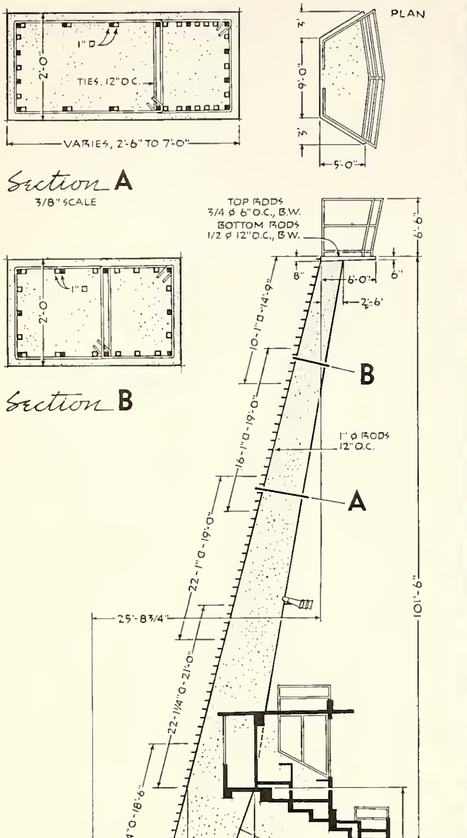
The history of the performance of concrete as a basic building material is long and varied. Improvements in the manufacture of cement, and laboratory methods for testing the aggregates and controlling the mixture, together with careful planning by the architect, now assure a prospective user of an end product that will have qualities and a useful life equal to that of any other material.

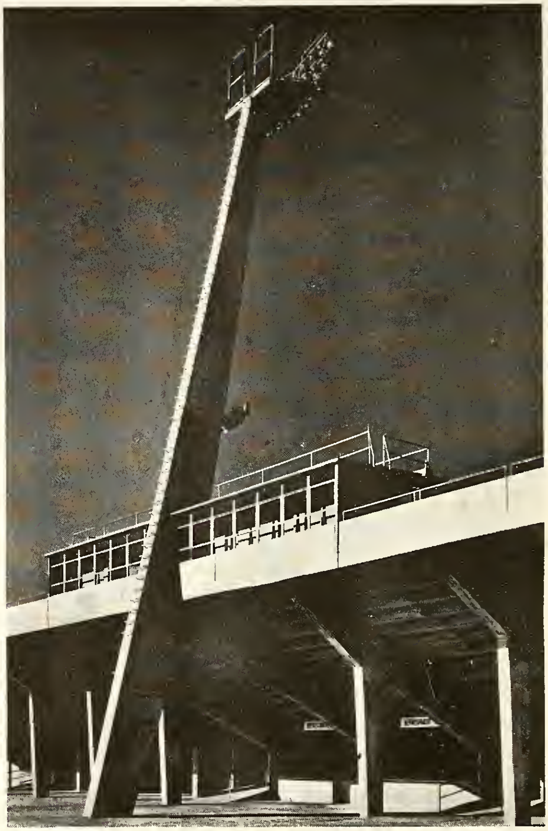
This fireproof concrete house was poured in two days. Exterior sandwich walls consist of two 3" concrete panels separated by a 1" layer of insulating material. Walls are waterproof and no condensation occurs on the inside surface. Interior finish is wallpaper or paint on concrete.

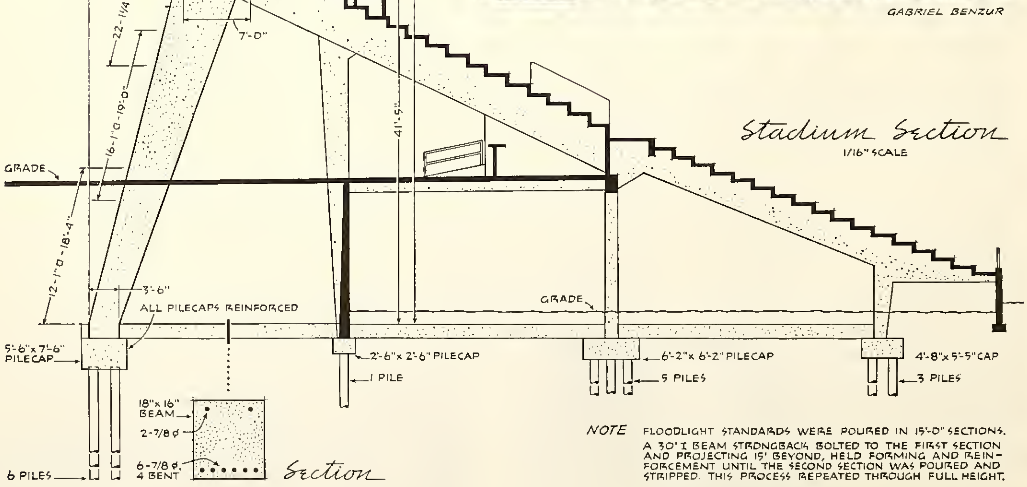
Photo at left shows steel forms being lowered into place. Cost of forms was amortized over a large number of houses. Location, Manhasset, L. I. Builder, Patrick J. Callan.

Photos: courtesy of builder

Stadium: Floodlights Standard




GABRIEL BENZUR



NOTE FLOODLIGHT STANDARDS WERE POURED IN 15'-0" SECTIONS. A 30' I BEAM STRONGBACK BOLTED TO THE FIRST SECTION AND PROJECTING 15' BEYOND, HELD FORMING AND REINFORCEMENT UNTIL THE SECOND SECTION WAS POURED AND STRIPPED. THIS PROCESS REPEATED THROUGH FULL HEIGHT.

HENRY GRADY HIGH SCHOOL
Atlanta, Georgia

AECK ASSOCIATES
Architects

Causes and Remedies of Plaster Cracks

BY V. H. NOBLE*

For the past few years, more than one and one-half million yards of gypsum plastering work has been finished daily on the walls and ceilings of buildings throughout the country. In the greatest majority of jobs, this plaster work has performed its intended purpose of providing a hard, smooth, monolithic surface that is sanitary and fire-resistant. Further, it has either provided its own decoration in the finish coat or has been ready for any subsequent decoration an architect or owner wished to employ. On a minor percentage of this vast acreage of plastering finished each day, however, some cracking has occurred—generally as a result of job conditions. These conditions may be structural weakness of the building, incorrect lathing, improper proportions or application of the plaster, atmosphere, or other causes. Such cracking requires spackling prior to final decoration, or other special cutting and repairing of the crack to eliminate it visually and to restore the monolithic appearance of the surface.

When cracking occurs, there is often a tendency to blame the gypsum-cement plaster, without considering that the gypsum cement comprises only about a quarter of the component materials in a plaster mix and without giving full consideration to either the base over which the plaster was applied or the conditions under which each was applied. Quite often, when plaster cracks occur in a unit, the plaster will be blamed because cracking did not occur in a similar unit. No two buildings, or parts of buildings, though alike in design and materials, can be built at the same time, under the same atmospheric conditions, and by the same mechanics.

plaster slab will not crack of itself

In considering the reasons for plaster cracks and determining methods which may be employed to avoid them, it should be understood that a plaster slab cracks only when some excessive external force is applied to it or when some excessive internal strains are produced within it. The stresses that are conducive to cracking may be introduced by movement in the building frame, by movement of other components of the building over which the plaster is applied, variations in atmosphere surrounding the slab, or a combination of these factors. It should also be understood that, quite generally, plaster slabs become more susceptible to cracking from such stresses as thickness is reduced, or aggregate ratio increased, thus creating a weaker plaster. As a corollary, the plaster can be cracked more readily if excessive stresses are encountered before the plaster is dry and has attained its full strength. With these important factors in mind, some of the problems and conditions that are conducive to cracking in plaster will be examined.

specifications

It would be well to start with the job specifications under which the lathing and plastering are to be performed. A few questions regarding them would furnish interesting information:

a. Do they clearly set the standards intended?

b. Do they show the lathing and plastering contractors what kind of materials shall be used and how they shall be installed?

c. Do they tell the contractor what proportion of gypsum-cement plaster to aggregate he shall use, to what thickness the plaster mix shall be applied, and so on?

d. Assuming that the specifications are clear and definite, is the job inspection of such a caliber that one can be sure that the materials being used, proportions, workmanship, and application are in accordance with the specifications?

Affirmative answers to these questions are important, for these factors can make the difference between a good plaster job and one which could result in objectionable cracking.

plaster bases

Unit masonry—gypsum block, clay tile, or porous cement block—must be sound, well laid in full mortar joints, properly anchored to door bucks at jambs and heads, and provided with good lintel support. Cement block should be well cured and stable, as green blocks are susceptible to shrinkage, often producing cracking within the block construction which can go through the plaster and become apparent as cracks in the plaster surface.

All metal and gypsum lath, the two most common plaster bases, should be properly installed. Improper nailing, poor tying, and excessive spans for the lath can easily result in cracking of the plaster slab. The American Standards Association in its Standard A42.4-1950, Specifications for Interior Lathing and Furring, describes the proper installation methods for all standard lathing; this data is supplemented by manufacturers' detailed specifications for standard lathing as well as special lathing systems.

Poor foundations or poor structural framing, whether in wood, steel, or concrete, often result in plaster cracks. These are structural defects and cannot be corrected in the lath and plaster work. The remedy is proper design and installation of the structural parts of the building.

care in mixing

When one understands that the gypsum plaster is a cement that is intended to weld the aggregate into a monolithic unit, the fallacy of spreading the cementing agent too thin can readily be seen. Normally, the scratch coat of plaster is proportioned with one part of gypsum-cement plaster (by weight) to two parts of aggre-

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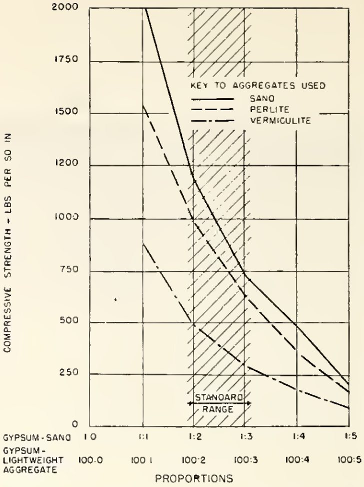
* *Products Engineer, Lath and Plaster, United States Gypsum Company.*



Right—chart of typical test results on dry plaster cubes, showing decrease in compressive strength as ratio of gypsum to aggregate decreases. Tensile strengths similarly decrease as aggregate ratio increases.

gate (weight of sand or cubic feet of lightweight aggregate); the brown coat is composed of one part of gypsum-cement plaster to three parts of aggregate. The scratch and brown coats together form the base coats of plaster, and are the backbone of the plastered surface. The finish coat is a thin veneer to provide surface leveling or texture only, and as such, does not add crack-resistance strength to the wall or ceiling.

If excessive quantities of aggregate are used, for example when the aggregate is porportioned to the gypsum in ratios of 4, 5, or 6 parts instead of 2 to 3, the gypsum-cementing agent will be spread so thin that it cannot adequately coat and bind the particles of the aggregate. Such a proportion materially decreases the strength of the plaster slab *(see chart)* and makes it more susceptible to failure under stress, thus less crack-resistant.

Lightweight aggregates used in proportions similar to those of gypsum-sand plaster—that is, 100 pounds of gypsum to 200 pounds of sand, as compared to 100 pounds of gypsum to 2 cubic feet of lightweight aggregate—typically obtain up to 85 percent of the set dry strength of the usual gypsum-sand mix. Although it is not possible to make a direct comparison of strength in crack resistance between two plasters having different aggregates, considerable caution should be used in permitting more than the normally specified amounts of aggregate, if a reasonable degree of safety against weak plaster surfaces is to be insured. Lightweight aggregates are generally satisfactory for use with gypsum plaster. With increased availability, both perlite and vermiculite are being used more frequently in small homes as well as in larger projects which often require higher fire ratings than sand aggregate will effect. Lightweight aggregates are particularly adaptable for this field.

Each type of lightweight aggregate requires job handling strictly in accordance with its particular characteristics. Perlite and vermiculite both require more mixing water than sand to bring the mortar to the proper application consistency. Vermiculite requires approximately twice as much water as sand to achieve the same plasticity; therefore, careful attention must be paid to heat and ventilation to remove the additional excess moisture from the plastered areas of the building. The same is true of perlite, but to a much lesser degree.

Both aggregates develop a higher degree of suction in the basecoat than sand, if allowed to dry completely. This condition often necessitates a light spraying of the basecoat with water in order to reduce the suction immediately before applying the finish coat of plaster.

Gradation of lightweight aggregates, as with sand, must be observed, and in addition, the lightweight aggregates must meet a weight specification. The standards for plaster aggregate are set forth in the American Standard Association's and manufacturers' specifications, and conformance to them will help materially in insuring quality plaster work.

thickness of plaster

There are definite standards established for the thickness of plaster over the various plaster bases: in no case can it be less than one-half inch. The allowance for the finish coat is approximately 1/16″, which requires the base coat to be 7/16″ for ½″ grounds. This is a minimum thickness for plaster over gypsum lath and gypsum tile. The standard for other masonry units and metal lath is ⅝″, including the finish over the surface of the plaster base.

Certain types of construction or fire ratings may require an increase in plaster thickness (and/or an increase in the gypsum to aggregate ratio) but never a thinner application of plaster than the standards established. Job experience indicates that thin applications of plaster often evidence cracking where normal applications to standard grounds do not. This condition is a direct result of the inability of thin sectional areas to resist external forces as adequately as thicker, normal applications of plaster. Thinner than normal applications of plaster are not conducive to good plastering.

heating and ventilating

Among the most frequent causes of plaster cracks are improper heating and ventilating conditions. Although the subject will not be discussed in this review, because of space limitations, the architect must, through specification and supervision, see that the subcontractor observes the proper heating and ventilating requirements for quality plastering.

other precautions for better jobs

Other precautions must be taken, as dictated by special job conditions.

steps to good plastering

major

1 sound structural frame
2 good plaster bases correctly installed
3 proper proportions of gypsum and aggregate
4 application to full standard thickness
5 adequate heat and ventilation

minor

1 set of base-coat plaster in normal range of 2 to 4 hours
2 trowel cutting base coat prior to set around openings

Radiant-heating systems present their own problems. Those systems with the heating medium embedded in the plaster slab require special provisions. The heating system should not be used for heating during or after plaster installation until the plaster is normally dry, thus having attained its full strength. Other means such as portable, "temporary" heat circulators should be employed during this period if weather conditions are cold enough to require heating to maintain an indoor temperature of over 55F.

To minimize cracking in those jobs having embedded tubing, it is also important to have at least a ⅜" thickness of plaster below the pipe or tubing. As the embedded tube decreases the sectional area of the plaster, this ⅜" minimum thickness below the coil is required to enable the plaster to resist stress adequately. The total thickness of plaster will be ⅜" minimum plus the outer diameter of the coil and its spacing from the plaster base which will vary depending on its alignment with the base.

Cracking at the corners of openings in plastered areas, such as doors, windows, access panels, recessed lighting fixtures, and so on, is often seen. Research and job experience have indicated that such cracking can be minimized by cutting the base coat plaster around these frames with the edge of the trowel after the plaster has been rodded level and before it sets. Cutting around the opening with the edge of the trowel to the plaster base, leaves a small space for expansion, so that a slight movement in the frame can be absorbed without exerting an excessive stress in the plaster slab. The application of the finish coat will conceal this cut space; it must be applied after the base coat has obtained greater strength.

Wherever wood window frames or door jambs serve as a plaster ground, it is well to prime coat the back adjacent to the plaster with a sealing type of paint which will minimize the absorption of moisture from the plaster. In addition, it is also well to trowel cut around them to provide some room for expansion.

This type of corner cracking has been equally troublesome at windows. Today, window frames are quite often metal, and provisions are made for radiators or convectors below the frame. The heat from the radiator or from the sun striking the metal sill or jamb can raise the temperature sufficiently to cause expansion and to induce a force in a plaster slab that has been brought up tight against it. By trowel cutting the base coat plaster along the edge of the frame at least 12" from each corner, space will be provided within which the sill or jamb can move somewhat without inducing a serious stress on the plaster slab. Here again, the finish coat will fill the surface of such a cut and bring the finished plaster surface tight to the metal frame. Where plaster is detailed flush with the face of the jambs, however, it is common practice to form a "V" groove in the finish coat to relieve a possible chipping of that surface.

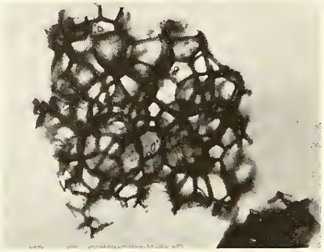
In thin-partition construction, such as solid plaster partitions, struts with excessive cross section are frequently used to fasten heads of bucks to the slab above. These struts can contribute much to the occurrence of "ear" cracks as they weaken the plaster surrounding them.

It is generally good practice to have all wires pulled through rigid electric conduit before plastering. Occasionally a wire may be difficult to pull, and if done after plastering, particularly when the plaster still contains free moisture and has not gained its full normal strength, sufficient force may be employed in pulling to cause cracking in the plaster.

This discussion has dealt primarily with plaster cracks that are through the base coat and the finish. In white coat finishes (gypsum gaged-lime putty trowel finish), a frequent complaint is craze cracking, an interlocking series of surface cracks in the finish somewhat resembling a net. This type of cracking, which often becomes evident at the time of painting, is usually due either to a low percentage of gaging plaster or lack of troweling. Lime putty does not set and it shrinks on drying. Gypsum-gaging plaster, in the proportion of about one part gypsum to two parts lime on a dry-weight basis, is blended with the lime putty to furnish a definite set and early hardness to the finish coat. By virtue of its characteristic of expanding on setting, it helps to eliminate "checking" due to shrinkage of the lime. When the amount of gypsum-gaging plaster is reduced below the recommended proportions, additional troweling, with water to lubricate the trowel on the surface of the finish, is required to avoid this check cracking. Thus, the remedy for this type of cracking is relatively simple: either use the proper amount of gaging plaster or trowel the finish more.

Perlite; Plaster Aggregate

Left: perlite ore blasted from side of mountain contains from two to five percent of trapped water. Ore is crushed and screened at mineside, shipped by rail to the expanding kiln. Below: photomicrograph of Permalite particle. Trapped water, expanded by heat, forms a sturdy, cellular structure.



Perlite, in its natural state a useless volcanic rock, has been successfully exploited by the Great Lakes Carbon Corporation and developed into a unique building material now marketed as Permalite. Perlite is first granulated, then expanded by heat. The end product, remarkable for its strength and light weight, is exceptionally suitable as a plaster and concrete aggregate, and has been employed successfully in many major installations in western United States.

plaster aggregate

Permalite, a plaster aggregate one-tenth as heavy as sand, weighs only 8½ pounds per cubic foot. When fire-tested by the Underwriters' Laboratory at Chicago, plaster made with this aggregate received the following ratings: on structural steel beams and steel floors, 4 hours; on structural steel columns, 3 hours; and on 2" x 4" wood stud partitions, 1 hour. The manufacturer states that this plaster possesses insulation qualities that are three times better than those of sanded plaster. Its 58 percent savings in on-the-wall weight will greatly reduce a building's dead load; structural designers will use this saving to adopt lighter structural members. Reduction of excess dead load will result in reduced building costs.

Typical brown coat application of Permalite - gypsum plaster. Compared with sand plaster, hawk load weight is reduced about two-thirds.

Permalite plaster is being employed in all brown and scratch coats in the 3010 rental units of the Park Forest project near Chicago. In this development, designed by Architects Loebl, Schlossman & Bennett, the total amount of plaster aggregate will run to 2600 tons, as against 26,000 tons of sand that would have otherwise been used. Talks with employees of McNulty Bros., plastering contractors for this project, have revealed other advantages, from the laborer's point of view, in building with this product. The aggregate, packaged in bags containing 4 cubic feet each and weighing only 34 pounds, can be easily moved and without waste from one location to another. Because of its lightness, the plaster is easy to trowel, rod, and darby, and will not slump on the wall. When workman fatigue is decreased, workmanship is improved. A large quantity can be stored within a building without exceeding a floor's allowable live load. As Permalite cannot freeze, winter plastering is greatly simplified. Sand pits that shut down after the first freeze will not constitute a threat to continued plastering operations.

In addition to the brown coat aggregate, Great Lakes Carbon Corporation has developed an acoustic plaster aggregate which weighs from 10 to 12 pounds per cubic foot. It is used in the finish coat and applied with a trowel. The particle gradation of this acoustic aggregate produces a plaster surface which, with a trowel finish, develops a noise reduction coefficient of .60.

concrete blocks

Recently, Permalite concrete blocks were made for testing at the Underwriters' Laboratory. The blocks were conventionally dimensioned in height and length, but were made only 4" thick instead of the usual 8". They were fire-tested and received a 4-hour rating. It is believed that this is the only 4-hour rating that has been given to a 4" concrete block by the Underwriters' Laboratory. The most advantageous use of this block will be as curtain wall backing for both steel frame and reinforced concrete construction. Steel reinforcement for this block has been designed by Fred Severud, New York engineer. As a result of a load test conducted by Theodore Crane, Professor of Architectural Engineering, Yale University, it has been established that this curtain wall backing will resist 150 pounds per square foot in horizontal stress. This figure exceeds the requirements for nonbearing curtain walls in New York City.

Permalite blocks weigh only 21 pounds per square foot. This figure represents a dead load saving of 59 pounds per square foot which would otherwise be imposed by a conventional 8" brick wall backing. These blocks have the same insulation value as one inch of cork and provide greater insulation than other 8" curtain wall backing units now in use. Employment of a 4" block furnishes the building owner with more usable floor area which provides increased revenue.

concrete aggregate

Extensive research has also been made in the use of Permalite in concrete. The concrete aggregate is somewhat coarser than the plaster aggregate and weighs about 14 pounds per cubic foot. The research has developed an excellent insulating and fireproofing concrete that weighs only 35-45 pounds per cubic foot, depending upon the mixture used. Permalite concrete will possess 10-13 times more insulating value than ordinary concrete.

All Permalite products are made according to A.S.T.M. specifications.

Fireproofing with Vermiculite Plaster

Vermiculite plaster aggregate weighs only about 216 pounds per cubic yard, compared with 2,700 pounds for sand. Vermiculite plaster weighs about one-third as much as sand plaster. One inch of vermiculite plaster fireproofing with its reinforcing and supporting channels weighs approximately 4 to 5 pounds per square foot.

Vermiculite concrete aggregate weighs about 8 pounds per cubic foot. In the 1-to-6 mix recommended for floor fill (1 part Portland cement to 6 parts vermiculite concrete aggregate by volume) vermiculite concrete weighs only 24 pounds per cubic foot, compared with 150 pounds for sand concrete.

A. R. Kellar, licensed structural engineer, Chicago, recently investigated the comparative weights of various systems of floor construction and their fireproofing. The following table and illustrations give the data obtained:

	Total Load	Dead Load	Dead Load per sq ft	Lbs of Dead Load Required to Support 1 lb of Live or Pay Load	Efficiency Rating of the Floor System Live Load to Total Load
Figure #1	81,150 lbs	56,700 lbs	98.5 lbs	2.32 lbs	30%
Figure #2	60,050 lbs	35,600 lbs	61.7 lbs	1.45 lbs	40%
Figure #3	54,000 lbs	29,550 lbs	51.3 lbs	1.21 lbs	45.3%
Figure #4	44,000 lbs	19,550 lbs	34.0 lbs	0.80 lbs	55.6%

The column spacing assumed was 24 feet each way. A live load of 50 pounds per square foot was employed in the design of each construction, which, with allowable reductions, resulted in a total live load of 24,450 pounds. Double beams were used as girders in all constructions to eliminate re-entrant plaster corners or angles which would be required to enclose the lower flange of deeper girders extending below the ceiling. The use of double-beam girders also cuts down story height with a saving in wall and partition materials.

In Figure 1, columns, girders, and beams are fireproofed monolithically with the sand concrete floor slab. Floor-beam spacing is 8 feet on center. The ceiling shown is for decorative purposes only.

Figure 2 shows the same framing used in Figure 1 with the monolithic fireproofing replaced with lightweight vermiculite-gypsum plaster on metal lath. The reduction in weight of fireproofing has made possible a substantial saving in steel.

Figure 3 employs a structural frame of columns, beams, and ties, in which the ties act as a unit in a system of open-truss joists, placed 2 feet on center, which support a 2½-inch-thick sand concrete slab. The ceiling is constructed with metal lath and vermiculite-gypsum plaster.

In Figure 4, a cellular steel deck is used, supported on floor beams on 8 foot centers, with a fill of vermiculite concrete topped with a hard finish of Portland cement, troweled smooth.

The weight of the plaster fireproofing around the columns will be 16 percent or less of the weight of the material indicated in Figure 1. The weight of column steel in the various constructions will vary almost directly with the total load. It will be about 81 pounds in Figure 1, 60 pounds in Figure 2, 54 pounds in Figure 3, and 44 pounds in Figure 4.

Is it possible for the architect and engineer to take advantage of this reduction in dead loads? Because of recent underwriters' fire ratings, yes.

FIRE RATINGS

In December 1939, Underwriters' Laboratories issued a fire-test report

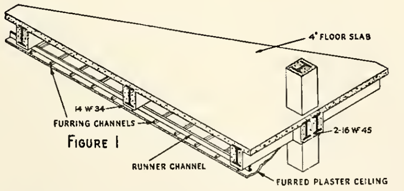


FIGURE 1

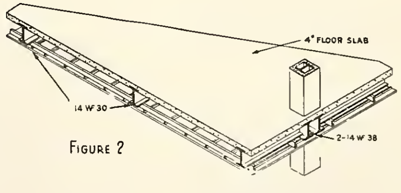


FIGURE 2

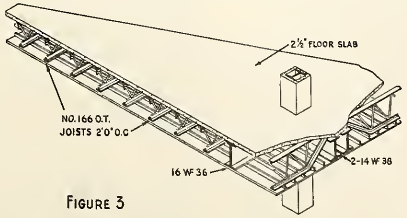


FIGURE 3

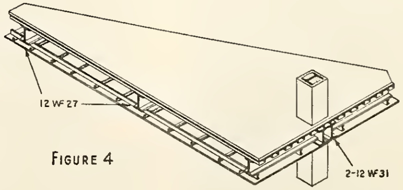
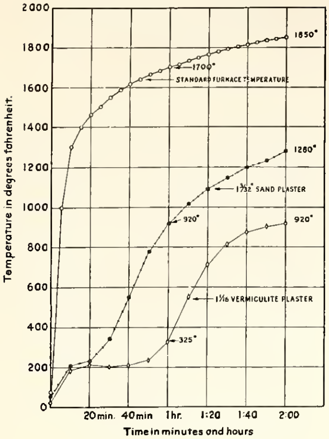


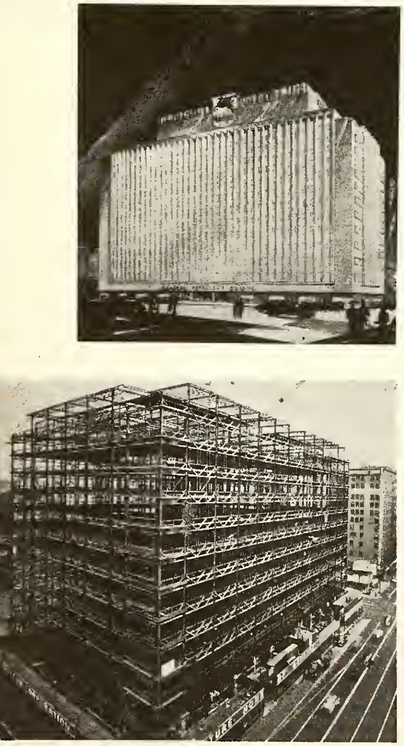
FIGURE 4

This article was prepared from data supplied to the editors by the Vermiculite Institute.

HEAT TRANSMISSION THROUGH GYPSUM PLASTER WITH SAND AND VERMICULITE AGGREGATE



Pictured below is the General Petroleum Building in Los Angeles, Calif., Wurdeman & Becket, architects. By using vermiculite plaster fireproofing, full advantage could be taken of light-gage steel construction. Resultant economies will allow this $7,000,000 structure to compete commercially with prewar office buildings.



that opened a new era in the fireproofing of structural steel, and made possible the design of lighter-weight buildings. The report gave a 4-hour rating to a steel floor assembly protected by less than a 1-inch thickness of plaster. The insulating agent which made possible this high degree of fire resistance was vermiculite, a lightweight, nonmetallic mineral belonging to the mica group.

This performance established vermiculite plaster as an efficient retardant. Its effectiveness is due to the complementary physical properties of vermiculite aggregate and gypsum plaster, which are as follows:

Vermiculite plaster aggregate is incombustible. It is made by expanding controlled diameters of vermiculite ore. A chunk of crude vermiculite has about a million laminations per inch. Trapped between these laminations and within the mineral are microscopic quantities of water. When the ore is heated in an expanding furnace to temperatures around 2000F, these water molecules are released, causing the layers to separate and move apart. Expanded granules of vermiculite aggregate contain thousands of dead air cells that act as insulators; and, in addition, the shiny, golden-surfaced laminations are efficient reflectors for turning back heat.

Gypsum plaster contains chemically combined water. Upon exposure to fire, this water is released in the form of cooling steam, or water vapor, when the temperature reaches the boiling point of water (212F). The plaster tends to remain at this temperature until all the water is driven off. By retarding the rate of heat transmission into the plaster, vermiculite aggregate slows down the calcination process, so that the chemically combined water in the gypsum is released at a slower rate. The cooling efficiency is thus prolonged, and the maximum fire-resistive value obtained.

The assembly which received this first favorable rating in 1939 was a cellular steel floor with a 2-inch concrete top fill and a suspended ceiling of vermiculite plaster, 7/8 inches thick, on expanded metal lath. The plaster was a mixture of 100 pounds of gypsum to 2½ to 3 cubic feet of vermiculite aggregate. The assembly was subjected to the standard fire-endurance test, fire-hose stream test, and excess-load test in accordance with the standard fire-test specification. It carried its normal load of 170 pounds per square foot without any evidence of distress during and after the fire endurance and hose stream tests, and during the cooling and drying period of 20 hours. After the 20-hour period, the assembly carried double its safe normal load without distress.

Official fire ratings for other types of assemblies incorporating vermiculite fireproofing became available in 1942, when the National Bureau of Standards report BMS-92 was issued. This report gave a 3-hour rating to a steel plate floor with 2½ inches of sand concrete topping and a ceiling of ¾ inch of vermiculite plaster on metal lath. The same assembly was given a 4-hour rating when protected with 1 inch of vermiculite plaster. A 2½-hour rating was given to a steel joist floor with 2 inches of sand concrete fill and ¾ inch of vermiculite plaster on metal lath; a 3-hour rating when the thickness of concrete was increased to 2½ inches; and a 4-hour rating when the thickness of vermiculite plaster was increased to 1 inch.

A number of fire tests were conducted subsequently at the Underwriters' Laboratories, Chicago. In 1944, a 4-hour rating was given to a steel "I" beam supporting a floor with 2 inches of vermiculite concrete fill and a suspended ceiling of 1 inch of vermiculite plaster on metal lath. A 1-hour rating was given a load-bearing wood stud partition with ¾ inch of vermiculite plaster on metal lath applied to both sides of the partition.

In 1947, Underwriters' Laboratories issued a 4-hour rating for a suspended ceiling of 1 inch of vermiculite plaster on metal lath as protection for steel construction, including beams, girders, etc.; also, a 3-hour rating for steel columns protected with 1 inch of vermiculite plaster on metal lath, with the lath spaced 1¼ inches from the column, and the space behind it on flange faces filled with plaster.

These ratings have been included in many city and state building codes and are being incorporated in others. The assemblies which have received the ratings can thus be detailed and specified by architects and structural engineers, with assurance of approval.

REDUCTION IN DEAD LOAD

Of equal interest to architects and structural engineers is the reduction in dead load and steel tonnage that vermiculite plaster fireproofing makes possible, particularly when lightweight vermiculite concrete is used as a floor fill.

How the reduction in dead load (indicated in four test panels at the beginning of this article) works out in actual practice in a multiple-story structure is shown by the original building in which vermiculite plaster and vermiculite concrete fireproofing were used: the Mercantile Bank Building, Dallas, Texas; Walter W. Ahlschlager, architect. It is a steel frame and brick-enclosed structure with 35 stories above grade and 2 stories below grade. The street-level floor contains retail stores, a lobby, and a driveway for customers to make deposits without leaving their automobiles. The main banking room occupies the 2nd floor. Above this are 11 typical office floors. At the 14th floor level, the floor area is reduced in size to form a tower which extends upward for 22 stories, 17 of which are office floors, the remainder being used for elevator machinery, house tanks, etc., and an observation room.

At the time the building was designed (1941), restrictions in the use of steel for building construction were being contemplated by the government. It was important to conserve as much steel as possible while maintaining a safe structure. Test data on the use of vermiculite plaster protection for primary beams and columns was not then available, but the National Bureau of Standards, when consulted, estimated that a 2-inch thickness of vermiculite plaster would give the 4-hour rating required by the Dallas code; and this was approved by the City Building Inspector.

The following summary shows the savings in weight, structural steel, and money effected by the use of vermiculite plaster and vermiculite concrete floor fill:

It should be noted that this landmark in lightweight, fireproof construction would not have been possible without the cooperation of Dallas building code officials. They, however, have always displayed a marked willingness to make use of Section 302 of their building code, "Alternate Materials and Types of Construction," so as to allow the use of new materials and constructions not covered by the code, when such materials are backed-up by the necessary test data.

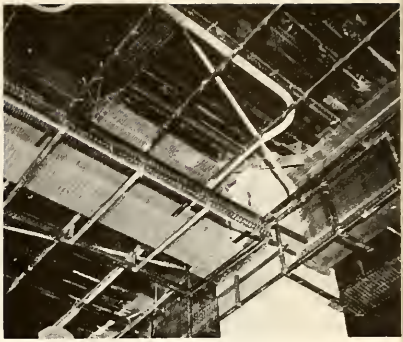
The superiority of 2-inch solid partitions of vermiculite plaster, compared with masonry, has been recognized for light-occupancy buildings, such as hotels, hospitals, and apartment houses, where the total floor area is considerably subdivided into relatively small rooms. Here, the loss of space occasioned by heavy, thicker-than-necessary partitions and larger-than-necessary columns can become a serious matter; and a fireproofing medium which is light, thin, and economical is an obvious solution.

TENSILE STRENGTH

It has been said that vermiculite plaster has less tensile strength than sand plaster. Actually, the difference is small. Laboratory tests show that sand plaster, mixed in the proportion of 100 pounds of gypsum plaster to 200 pounds of sand (2 cubic feet) has a tensile strength of 220 pounds per square inch; in the proportion of 1-to-3, 160 per square inch. Vermiculite plaster, mixed in the proportion of 100 pounds of gypsum plaster to 2 cubic feet of vermiculite aggregate, has a tensile strength of 150 per square inch; in a 1-to-3 mix, 100 per square inch.

This difference in tensile strength is likely to be less under actual job conditions. Better control in mixing can be exercised with vermiculite aggregate, because a bagged material

Item	Weight Concrete	Weight Vermiculite	Reduction in Dead Load
Floor area 400,000 sq ft	68#/sq ft 27,200,000# total	25#/sq ft 10,000,000# total	17,200,000#
Beams 41,985 lin. ft	225#/ft 9,446,625# total	12#/ft 503,820# total	8,942,805#
Columns 14,082 lin. ft	389#/ft 5,477,898# total	25#/ft 352,050#	5,125,848#
Total Floors, Columns & Beams	42,124,523#	10,855,870#	31,268,653#
Total Reduction in Dead Load			15,634 tons or 74%
Total Structural Steel Required: Using Vermiculite Concrete over Cellular steel floors and fireproofed with Vermiculite Plaster)			6,280 tons
Structural Steel Saved:			1,880 tons or 30%
Economy: 1,880 tons at $125 (1941 prices)			$235,000



Furring around beams and girders, and for suspended ceiling, are shown before and after vermiculite plastering in the photos above of the Register and Tribune Building in Des Moines, Iowa, designed by Architects Brooks and Borg. Preparation for closer fireproof plastering is shown below, in the John Hancock Insurance Co. Building in Boston, Mass., Cram & Ferguson, architects.

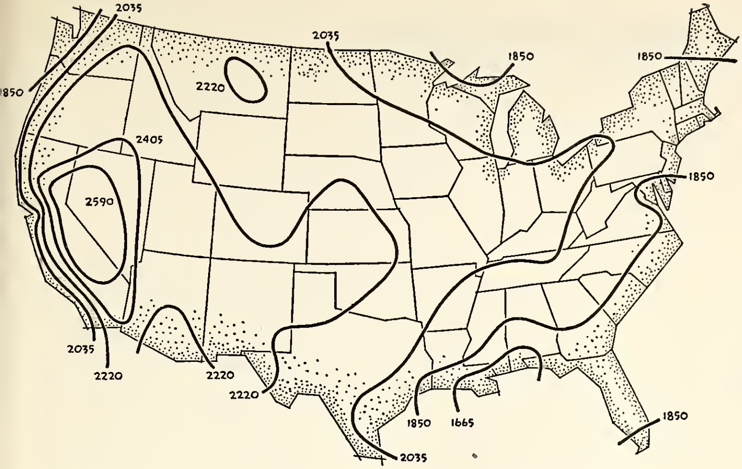
is easier to proportion, and the plaster is less apt to be mixed lean. Vermiculite aggregate is uniform in size and quality and is free from foreign matter. All these factors have a bearing on the strength and uniformity of the finished plaster.

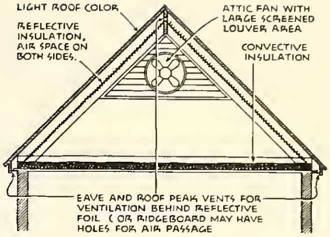
Vermiculite plaster is resilient and will absorb considerable shock or impact without shattering. Nails and picture hooks can be driven into it without causing unsightly cracks. It can be readily cut, and the carpenter's finish work is consequently made easier.

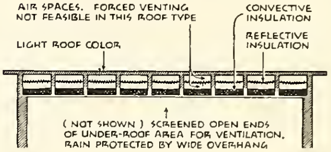
COST—AVAILABILITY

Plasterers like vermiculite aggregate because of its easy application and light weight. Vermiculite plaster does not have a tendency to pull loose and fall off before it has a chance to set—a decided advantage to the plasterer on ceiling work. It is mixed and applied like ordinary sand plaster, and any plasterer who can apply sand plaster can apply vermiculite plaster (see photos at left). Vermiculite aggregate eliminates the labor of breaking up and thawing out a frozen sand pile in winter. There is no waste, and on small jobs the necessary number of bags can be thrown into the back of a passenger car and taken out with the crew. The aggregate is so reasonable in cost that its advantages make it desirable for all types of plastering, however low the cost of sand may be.

During the past five years, the vermiculite industry's production of vermiculite plaster and concrete aggregates has increased enormously. The supply of crude ore is virtually unlimited, and constant improvements have been and will continue to be made in mining, milling, and processing equipment and technique. The postwar resumption of industrial and commercial construction that must be fireproofed, and the light weight, economy, and dependability of the material call for even greater production; the industry expects to be able to meet the demand.




LIGHT ROOF COLOR
REFLECTIVE INSULATION, AIR SPACE ON BOTH SIDES.
ATTIC FAN WITH LARGE SCREENED LOUVER AREA
CONVECTIVE INSULATION
EAVE AND ROOF PEAK VENTS FOR VENTILATION BEHIND REFLECTIVE FOIL (OR RIDGEBOARD MAY HAVE HOLES FOR AIR PASSAGE


AIR SPACES. FORCED VENTING NOT FEASIBLE IN THIS ROOF TYPE
CONVECTIVE INSULATION
REFLECTIVE INSULATION
LIGHT ROOF COLOR
(NOT SHOWN) SCREENED OPEN ENDS OF UNDER-ROOF AREA FOR VENTILATION. RAIN PROTECTED BY WIDE OVERHANG

INSULATION—MONEY IN THE BANK

A glance at the above map of the United States tells one the amount of average solar radiation received at the ground in Btu per day during July. A similar chart for January would show a variation of 370 to 555 Btu along our northern border and a range of 925 to 1110 Btu along the boundary at the south. It is apparent, therefore, that thermal insulation in both residential and commercial construction should produce significant economies for both summer and winter operation. As Groff Conklin points out, however, the average up-to-date multi-family apartment house and hotel, and most hospitals, office buildings, factories, public buildings, and lofts being built today omit insulation in the outer shell (*following article*). One cannot help but wonder why such a situation obtains in these structures when practically the opposite exists in residential construction. It is specially incongruous as the assumption has always been that the commercial structure was erected primarily as a healthy investment for its owner! In his discussion, Conklin presents provocative evidence that the extra cost of wall insulation and the use of insulating-glass units can be amortized by fuel savings in a relatively short period during the life of a commercial structure. All savings beyond that point, of course, are money in the bank!

A wealth of data on acoustic insulation has been gathered together and presented in the three remaining articles of this section (*pages 167 to 179*).

New Directions in Thermal Insulation

BY GROFF CONKLIN

THE PROBLEM OF NONRESIDENTIAL STRUCTURES

Time was when all an architect had to do was to enclose space esthetically or cheaply. Sometimes he did both and was called a genius. But that was just about all he did. People were used to spending lots of money for coal in the winter and being hot indoors in the summer.

Today, however, the architect has to be more than esthetic, economical, and aware of a few important engineering stresses. He has to know a little about heat engineering, and acoustics, and insulation materials. He has to know something about natural and artificial ventilation, and sun control devices, and microclimatology, and dozens of other things. The days are past when a man who carried a rafter table in his head was a leader in his profession. Today the man who counts is the bulbous-browed type who can remember the conductivity of dried algae and the perm rate of peanut-oil-base paint (if any).

In other words, the architect has to think of buildings dynamically today. They are no longer tiers of brick or slabs of wood with holes in them to see through. They must *perform*, thermally speaking. They must be efficiently operating cost-savers and comfort-givers, not just inanimate shapes providing shelter from the elements.

In the modern residence it is taken for granted that thermal insulation is the means which most economically and efficiently enhances interior comfort and livability the year round—insulation and, in some parts of the country, double glazing. But in larger buildings of different function, the answer to the question of operational economy and human comfort and efficiency is considerably less clear. Indeed, it can be said to be murky.

For example, the average up-to-date multi-family apartment house and hotel, and most hospitals, office buildings, factories, public buildings, and lofts being built today, omit insulation in the outer shell, especially if the glass area in the wall is large. Naturally, there is a sizable increase in annual operating costs to pay for the unnecessary heat loss in the winter, and also for the equally unnecessary heat gain in the summer for those buildings that have air-cooling systems.

Roofs generally are insulated, though in the 20-story building not so much for economy's sake as for the sake of making the top floor more comfortable in hot weather. Heat loss in winter is reduced, of course, but the proportionate size of the roof area to the areas of the walls in a multi-story building is often so small as to make the fuel saving a vanishing factor.

Why, one cannot help wondering, is this seemingly wasteful difference in common practice between the completely insulated residence and the nonresidential building with no insulation in its walls and no double glazing, permitted to exist? The reasons are difficult to state logically, perhaps because they are not logical in themselves.

Certainly no sound reason can be given for the omission of thermal insulation from the walls of buildings which are not all glass. The cost of materials and installation can be absorbed by savings in the heating plant and in fuel, as will be shown later. When the nonresidential structure is largely a curtain of glass, as certain types of buildings are today, the question of the advisability of using the much more costly double glazing arises, bringing with it the serious problem of an inordinately increased original investment—or so, at least, most investors in new buildings undoubtedly tend to think.

But are they right? The question is simple. Will the savings resulting from smaller heating plants and radiator areas, plus the savings in fuel consumption over a reasonably short period of years, warrant the extra initial expenditure for the double glazing?

The answer depends on whom you talk to. In general, it is believed that double glazing is too expensive and that the savings would not balance the cost within a reasonably short number of years. The same reasoning must apply to wall insulation as well, too, since so many nonresidential structures are built without using such materials.

But is this thinking sound? Let's take a look at a few plain, physical facts.

Glazing. The heat loss coefficient, or U factor, for a piece of ordinary window glass is 1.13. This means that 1.13 Btu of heat will pass through one square foot of glass every hour for each degree of temperature differential on the two sides of the glass. On the other hand, the U for the thinnest double-glazing unit, which has about ¼″ air space between the sheets of glass, is given as 0.61 Btu. The ¼″ double glazing thus saves almost one half of the heat normally lost through glass—exactly 0.52 Btu per square foot per hour per degree difference in temperature.

Of course, should an ingenious architect design double windows—not airtight but normally snug—to be built so that they are at least ¾″ apart, he could achieve a heat loss of only 0.54 Btu, the average loss for a double window that takes full advantage of the insulating value of an air space. According to National Bureau of Standards tests, that space should be no less than ¾″ wide for maximum insulating efficiency—not the ¼″ or ½″ that commercial double-glazed window units are made in.

Walls. Here the situation is equally startling. Take the popular (and expensive) cavity wall, which is being used in so many institutional structures today "in place of" insulation. This wall does take advantage of the full insulating value of an air space; the only thing wrong with it is that the air space, unlike glass, can be filled with an insulating material with a much higher heat-saving efficiency. If you did this with a double-glazed window you would have a considerably better insulating efficiency, but you would not have a window.

Actually, the air space in a cavity wall is not an efficient insulator. An enclosed air space ¾″ or more in width has a heat loss of 1.10 Btu when it is vertical, and about 1.31 when it is horizontal, as in roofs. The heat loss factor of an inch of mass insulation is between 0.24 and 0.33, depending on the material. The conductance of two air spaces in a rafter or stud space (one reflective aluminum surface facing each space) is between 0.09 and 0.27, depending on the position of the insulation and the season of the year. Two inches of mass insulation and three reflective air spaces are even more efficient.

And yet some very large and very important buildings—hospitals, factories, office buildings, apartments—are being built today with cavity walls using the air space as insulation. A 4″ common brick has about the same heat-insulating quality as an air space—its heat loss factor is around 1.25, which is only 0.15 Btu higher than the heat loss of a vertical air space.

The over-all heat loss of a typical brick-tile cavity wall construction ranges between 0.27 and 0.30, depending on the size of the openings provided for cavity ventilation, according to the latest tests by the National Bureau of Standards. On the other hand, the heat loss factor of the SCR insulated cavity wall now being promoted by the Structural Clay Products Research Foundation, with its 2″ of mineral wool insulation in the cavity, is claimed to be 0.12 when plastered, and only slightly less efficient when the plaster is omitted.

Likewise, a solid 8″ common-brick wall plastered over gyplath on 1″ furring strips, has a U of 0.27. The same wall with 1⅝″ furring and the space filled with flexible mass insulation has a U of 0.11. A 4″ brick—8″ cinder block wall, plastered over gyplath on ⅜″ furring strips, has a U of 0.22; with 1⅝″ furring strips and flexible insulation, the U is 0.10.

In all these cases, the solid part of the wall of any building becomes over 50 percent more efficient as a preventer of heat loss when it is insulated than when it is not. Together with double glazing, which approaches the insulated wall in heat-saving efficiency, the wall-and-window complex can be considered to be an enormous heat trap in winter and a heat barrier in summer—a much more economical element in the operation of a building, and much more comfortable for its human occupants into the bargain.

Table I: Comparison of Radiation in Various Buildings With and Without Insulation

HOSPITALS COMPLETED	C.F. of Building	S.F. of Radiation	No. of C.F. to Ea. S.F. of Radiation	Insulation Walls	Insulation Windows
Prince Edward Island, Canada...	550,000	5,100	107	Yes	Yes
Bethlehem, Pa.	750,000	3,750	200	Yes	Yes
Hagerstown, Md.	560,000	3,590	156	Yes	Yes
New Haven, Conn.	1,605,000	13,248	121	Yes	Yes
Toronto, Ont.	1,880,000	16,600	113	Yes	Yes
HOSPITALS BEING PLANNED					
Scranton, Pa.	333,000	3,343	99	Yes	No
Long Island	514,000	7,320	70	Yes	No
New Jersey	425,000	6,600	65	No	No
Glens Falls, N. Y.	605,000	7,400	85	Yes	No
Virginia	1,137,521	23,813	47	Yes	No

In the first group all except Prince Edward Island are wings added to existing structures.

Table II: Hospitals With All or a Portion of the Buildings Insulated

No.	Location	No. Beds	Days Care	Total Cost	Power, Light and Heat Cost Per Bed Per Yr.	Power, Light and Heat Cost Patient Per Diem	Proportion Insulated
	Toronto, Ont.	547	175,488	$ 40,622	$ 74	$0.23	1/2
	Prince Edward Island, Canada	200	54,037	19,373	97	.36	All
	Hagerstown, Md. ..	170	57,783	27,718	163	.48	1/2
	Glens Falls, N. Y. ..	162	59,208	19,048	117	.32	1/2
	Bethlehem, Pa.	307	89,001	58,153	188	.65	1/4

Hospitals Which Are Uninsulated

No.	Location	No. Beds	Days Care	Total Cost	Power, Light and Heat Cost Per Bed Per Yr.	Power, Light and Heat Cost Patient Per Diem	Proportion Insulated
2	New York City.....	520	152,686	$163,129	$314	$1.07	
3	Brooklyn	341	96,966	117,897	346	1.22	
8	New Jersey	284	71,856	71,367	251	.99	
10	Long Island	236	69,040	77,023	326	1.12	
13	Central New York State	218	66,323	43,509	200	.66	
14	New Jersey	207	56,588	65,317	316	1.16	
19	Northern New York State	150	41,959	27,828	186	.66	
20	New York City.....	131	29,741	58,541	447	1.97	
22	Connecticut	134	36,157	43,130	322	1.19	
25	Long Island	110	32,843	36,775	334	1.12	
29	Westchester County, N. Y.	100	28,261	33,975	340	1.20	
35	Brooklyn	143	30,288	43,875	307	1.45	

The local figures are from a group of hospitals with uniform accounting.

But these are suggestions for tomorrow. Today the enormous majority of nonresidential buildings use no thermal insulation or double glazing of any sort, whether they are half a century old or still under construction. Is there any experience on the record to indicate whether or not this curious sticking to obsolete methods has any rhyme or reason? There is—and it is all in favor of the use of modern insulating materials in nonresidential structures.

A pioneer in this still extremely limited field is a man named Charles Neergaard. It was through his efforts that what was probably the first insulated nonresidential building in the United States, and certainly the first insulated hospital, was built about 15 years ago.

Neergaard is a hospital consultant, an enthusiast grown old in the service of efficient and economical design for the nation's hospitals. He has been laboring in the vineyard for more than 30 years, and has innovated a large number of important elements in hospital design. Probably the innovation of greatest long-term importance and most general application is the insulation of walls and windows in nonresidential structures.

Neergaard's first insulated hospital was built in Hagerstown, Maryland, in 1936. As he himself puts it, this was "*the first, and for a long time the only, multi-storied steel frame building in the East with completely insulated walls and windows.*"

The resultant savings in the Hagerstown hospital are on the record. Permanent double glazing in roughly 28 percent of the wall area cost about $2.25 more per square foot installed than the double-strength glass it replaced. Three-inch insulating blocks that could be plastered cost about $0.20 a square foot more than the furring tiles and lath they replaced in 72 percent of the wall. And the pragmatic realities of this installation, as Neergaard tells them in the March and April 1950 issues of *The Modern Hospital*, were that the actual reduction in necessary investment for heating plant and radiation surfaces in the new building was essentially the same amount as the added cost of the insulation and the double glazing. The very sizable savings in operating costs resulting from lowered fuel consumption have been added to the net income column every year since.

That this rather startling economic fact is not completely out of line with reality is indicated by other savings figures from other hospitals built since, as shown in Tables I and II, reproduced from Neergaard's *Modern Hospital* article, with some slight modifications.

These savings are not, of course, the only benefits insulation has brought the hospitals. Convection currents from uninsulated windows and walls, an unpleasant and, in a hospital, often dangerous, winter problem (they usually mean a rise in respiratory illnesses) are practically eliminated in the well-insulated building.

In addition, actual tests conducted in the Hagerstown hospital showed that the insulated building was on an average eight degrees cooler indoors than the older uninsulated structures which were a part of the same hospital. The summer comfort factor is, of course, important not only in hospitals, where it is of the utmost importance, but also in any other structure in which human beings live or work during the dog days.

There is another point about wall insulation and double glazing that Charles Neergaard believes should be taken into account. This is the increase in acoustical insulating value that a wall of that nature gains over the uninsulated wall. The available figures are obscure in this respect, but there can be no doubt that there is considerable improvement in the acoustical insulating qualities and the barring of outside noises in such buildings. In cities as noisy and as distracting as our modern megalopolises, sound reduction is an important factor, especially on the lower floors of large buildings.

Neergaard likes to remark on the fact that nonprofit buildings like hospitals were the first to take up this sort of modern, efficient, economy-producing construction. He finds it difficult to understand why the supposedly hardboiled and profit-conscious owners of modern multi-storied office buildings, apartment houses, or what have you, simply let all that heat go to waste and uncomplainingly foot the bill for it. The cynic will say—oh, well, they take it out of the tenants' hides. But the answer is that they could still charge exactly the same rents as they do today and could actually add all those dollars' worth of fuel saved to their profit account.

But they don't—perhaps because, like any other client, they don't know what to ask for. They don't realize that these savings can be made, never having been told.

On the other hand, there are trends leading toward a more rational approach to the nonresidential wall. For example, Skidmore, Owings & Merrill's design for Lever House, recently completed in New York, called for cellular-glass block insulation in the spandrels. Then there is the insulation-filled cavity wall promoted by the Structural Clay Products Research Foundation, previously described — a really efficient heat-saver. There are wood-fiber-cement, wall insulating slabs that are nonstructural but self-supporting. Unlike most other insulations currently on the market, these can be plastered directly, something which is not true of cellular-glass blocks. Insulating lath can be plastered, of course, but it is not self-supporting, nor is it incombustible.

John D. Maultsby & Company, architects for the $3 million, nine-story Brotherhood Building in Kansas City, Kansas, are reported to have cut the initial cost of the heating equipment 20 percent and lowered refrigration capacity from 750 tons to 600 tons by using double glazing (outer lights are of heat-absorbing plate); they also anticipate comparable savings in operation.

In general, however, architects are still doing little about double glazing. The original cost automatically scares them off before they have taken a good second look at the possible savings in heating plant and in fuel. One of the largest veterans' hospitals in the East is being built with standard, old-fashioned single glazing and with cavity wall construction. Undoubtedly the heating plant is far larger than it need be, if previous experience is any guide. The annual loss in heating dollars alone would make angels weep, if they cared at all about human waste and human inefficiency.

Of course, as L. V. Teesdale of the Forest Products Laboratory, U.S. Department of Agriculture, has pointed out, "It is hardly practical to add insulation or double glazing to most large structures after the buildings have been completed. Such features should be incorporated in the plans as part of the design." Consequently, all existing buildings that are uninsulated must remain so, and their owners take their annual loss in wasted fuel with a smile.

But in new buildings double glazing is likely to prove a sound investment. Teesdale writes, in connection with the new Forest Products Laboratory building in Wisconsin: "Double glazing . . . in Madison, where we have about 7400 degree days, could bring about a fuel saving of as much as 88,800 Btu per square foot. With coal costing $10 per ton, and allowing eight pounds of steam per pound of coal, the fuel saving would be about 5.55 cents per square foot of glass surface. In our buildings we have about 20,000 square feet of glass. If double glazed, the estimated reduction in fuel would be 111 tons of coal per year. Double glazing now would not be justified on the basis of fuel savings but double glazing would have been justified at the time the building was under construction."

These are persuasive figures indeed, particularly since they do not take into account either the further savings in initial investment resulting from a smaller heating plant, or the somewhat smaller savings caused by insulating the nonglass areas of the walls. If these figures were added, the savings would in all probability be extremely handsome. (*See Chart 1 for a theoretical example.*)

It is not possible to make an entirely valid and pragmatic judgment of the value of insulation in nonresidential walls at this point, of course. For one thing, it has not actually been proved that insulation and double glazing in the typical nonresidential structure can be made economical. All that has been shown is that such construction has proved economical in certain hospitals. Practical proof must be forthcoming from practical men who can bring their experience and knowledge to the problem and analyze the various costs versus savings so as to come out with an answer that is essentially right. At present the indication is that their calculations will show that insulation and double glazing in many types of nonresidential—and apartment house—structures are good investments.

For example, nearly four years ago James Govan, a Toronto architect who has built many insulated buildings, particularly hospitals, in the Canadian provinces, published the following unqualified statement in *Canadian Hospital* (June 1948):

CHART I: EXAMPLE OF POSSIBLE ECONOMIES RESULTING FROM INSULATING WALLS IN NONRESIDENTIAL STRUCTURES[1]

situation

Imagine a test building 100 feet square and 25 feet high, or one containing 10,000 square feet of wall area. Fifty percent of this area is fenestrated and the remainder consists of brick and cinder-block construction. Location: New York City vicinity. As the roof and door openings are identical in buildings with insulated or uninsulated walls, they may be considered as cancellable and therefore ignored; floors also not to be considered.

analysis of heat loss

UNINSULATED WALLS	
A. 50% of wall single glazing. 5000 sq. ft. x 1.13 (U)	5650
B. 50% of wall 4" common brick, 8" cinder block, ½" plaster on block. 5000 sq. ft. x 0.33 (U)	1650
TOTAL HEAT LOSS, Btu/hr./deg. diff.	7300
INSULATED WALLS	
C. 50% of wall double glazing, ¾" air space[2] 5000 sq. ft. x 0.54 (U)	2700
D. 50% like 1-B (*above*) plus insulation with heat transmission coefficient of 0.15. 5000 sq. ft. x 0.10 (U)	500
TOTAL HEAT LOSS, Btu/hr./deg. diff.	3200
NET SAVINGS IN REDUCED HEAT LOSS 7300-3200	4100

savings in fuel costs per year

Annual degree days of heating in the New York City area	5300
Calculated efficiency of oil burner for steam heat	75%
Fuel consumed, if U is 1.00/sq. ft./yr. in N.Y.C.[3]	1.5 gal.
TOTAL GALLONS TO REPLACE HEAT LOSS IN UNINSULATED WALLS	
A. Fuel for 5000 sq. ft. of glass 5000 x 1.5 = 7500 x 1.13	8475 g.p.y.
B. Fuel for 5000 sq. ft. of wall 5000 x 1.5 = 7500 x 0.33	2500 g.p.y.
TOTAL	10,975 g.p.y.
TOTAL GALLONS TO REPLACE HEAT LOSS IN INSULATED WALLS	
C. Fuel for 5000 sq. ft. of double glazing 5000 x 1.5 = 7500 x 0.54	4050 g.p.y.
D. Fuel for 5000 sq. ft. of wall 5000 x 1.5 = 7500 x 0.10	750 g.p.y.
TOTAL	4800 g.p.y.

NET SAVINGS OF INSULATED OVER UNINSULATED WALL IN G.P.Y.

10,975 — 4800 = 6175 gallons. At 0.125¢ per gallon, this means a cash saving in fuel costs per year of $775.

estimated savings in reduced size of heating plant and radiation area[4]

Heat loss for OF — 70F temperature differential, uninsulated building: 7300 x 70 = 511,000 Btu/hr. At 75% burner efficiency	640,000 Btu/hr.
Heat loss for OF—70F temperature differential, insulated building: 3200 x 70 = 224,000 Btu/hr. At 75% burner efficiency	280,000 Btu/hr.
DIFFERENCE	360,000 Btu/hr.

NET SAVINGS IN DOLLARS IF PLANT COST IS $8 PER POUND PER HOUR CAPACITY[5]

$$\frac{\$8 \times (360{,}000)}{1000} = \$2900 \text{ (approximate)}$$

estimated cost of insulating and double glazing[6]

Double glazing: At $2.25 extra per sq. ft. 5000 x 2.25	$11,250
Wall insulation: At $0.20 extra per sq. ft. 5000 x 0.20	1,000
TOTAL EXTRA COST	$12,250

summary

Total Extra Cost	$12,250
Savings on Steam Plant and Radiation	2,900
DIFFERENCE	$9,350

NECESSARY PERIOD TO AMORTIZE EXTRA COST OF WALL INSULATION, DOUBLE GLAZING

$$\frac{\$9{,}350}{\$775 \text{ (Fuel savings per year)}} = 12 \text{ yrs.}$$

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[1] *This example does not take into account the further savings which would result if the building were also air-cooled.*

[2] *It should be noted that at the present time there is no standard double-glazed window unit with a ¾" air space between the sheets of glass. The maximum width of air space commercially available is ½".*

[3] *Based on data in "Insulation: Where and How Much" (Housing and Home Finance Agency, 1950).*

[4] *Does not take into account necessary added plant to take care of heat loss through roof, doors, floor, etc.*

[5] *"Chemical Engineer's Handbook," John H. Perry (McGraw-Hill Book Co., Inc., 1950).*

[6] *Based on data developed by Charles Neergaard ("The Modern Hospital," March and April. 1950).*

"Canadian owners and architects should know that there is absolutely no need for increased capital expenditure to provide increased thermal capacity because its cost can and should come out of the reduction in expenditure of the heating plant provided."

Since some of the most successful insulated hospitals are in Canada and have been a part of Govan's experience, it should be taken for granted that there is a wealth of supporting facts behind this quotation. And further support is brought to his position by the opinion of Engineer C. E. Daniel, who was consulting engineer to Hoge and Shaffer in the preparation of the U.S. Public Health Service's report, "Functional Basis of Hospital Planning." According to Charles Neergaard, Daniel was personally responsible for the following quotation from that report.

The statement is preceded by an engineering generalization that one square foot of radiation is required for every 80 cubic feet of the building when it is uninsulated. It then goes on:

"When the walls are well insulated, the size of the heating boilers and radiators can be reduced approximately 25 percent; if, in addition, the windows are effectively double glazed, 50 percent, or approximately one square foot of radiation to 160 cubic feet of space."

Without question, such a reduction in heating plant size will, in many if not all instances, essentially cover the costs of the insulation.

Now no generalization ever proves true in a specific case. That is probably why it is called a generalization. Nevertheless, the above quotations should indicate to architects, to engineers, and to clients of both, that there is literally no logic or sense in continuing to assume *automatically* that the insulation of nonresidential buildings (including double glazing) is uneconomical, will add seriously to the capital investment, and will not drastically reduce operating costs. On the evidence, such insulation should long have been one of the standard and basic elements in the planning of modern nonresidential buildings.

Meanwhile, there are other aspects of the problem that deserve study. For example, what are the basic elements that make insulation in the home a good investment? Can they not apply to the nonresidential structure as well?

Ideally, housing construction economics in the case of individual homes with four sides exposed to the weather, or with two, in the row house, or three, in the semidetached, are based on a combination of a program of low first cost, high operating efficiencies, and minimal maintenance costs. Large glass areas in private homes are, when well planned, designed to take fullest advantage of solar heat during the cold winter days. They can be effectively curtained against cold night air or during sunless days, if desirable. Removable storm windows for residences, too, are generally inexpensive, and provide excellent insulating efficiency at the window openings for very little money. Insulating materials for walls, attics, and floors that need them are cheap in general and very efficient. It is far from uncommon to find that the cost of insulation and storm windows in residences are paid for by the savings in the cost of a smaller heating plant and decreased radiating area or smaller warm-air ducts. If any part of the insulating bill is still outstanding, it is in most cases amortized in a very few years by the savings in fuel costs resulting from using a smaller furnace. This is the usual experience in the modern residential field, as any architect practicing in it knows. Problems in moisture condensation and humidity control are being handled with increasing ease by means of efficient vapor barriers and simply designed ventilating systems, often natural rather than powered.

In other words, insulation has arrived for the residence. True, storm windows are often used instead of prefabricated double glazing, but the result is the same, and is achieved at considerably lower cost.

The situation in commercial, industrial, and institutional structures, on the other hand, is seemingly of a very different nature. In the first place, it is true that one generally cannot pay the kind of attention to the solar orientation of a nonresidential structure as you can to the private home. A city block is an immovable object. Nonurban structures in this general class, whether resort hotels, decentralized factories and hospitals, or some other type of free structure, can be designed to take the fullest advantage of site and sun. In the city, however, this is practically impossible. A favorable location sun-wise is fortuitous, not planned.

But that is just about the only important limitation to the control of internal climate that the urban building suffers from. Otherwise insulation, combined with modern heating and air-conditioning techniques, should be able to provide a highly efficient and comfortable structure that will please its owner by the low costs of operation and its tenants by the unusual elements of comfort, winter and summer, that it provides.

And yet most of these building are not insulated. Some of the reasons given for not insulating the walls of buildings in the nonresidential categories are novel in the extreme. During the researches on this subject, the following were mentioned:

1. *It doesn't make any difference; the tenants pay for the heat anyhow.* (This one was mentioned before, but it deserves repetition.)

2. *It would be too difficult to explain the higher cost for double glazing, etc., to the client.* (In this case the possible savings in the heating plant were not admitted, even though they were mentioned several times.)

3. *The office building* (and others in similar categories) *is occupied only eight hours a day, so why insulate for nighttime? The sun will take care of the heat loss during the day.* (On the north side, too? . . . And also, one cannot design any building to be occupied by paying tenants on the assumption that the temperature can be permitted to fall below the comfort level during the night. If the owner can control the occupants and knows they will not be in the building after dark, the point may have some validity—except that it still is no answer to the problem of heat loss!)

4. (From an engineer's letter)—*"I cannot recall a single instance in 30 years of engineering that placed the decision for or against insulating a building into my lap."* (In other words, "The client never suggested it.")

5. *Rooms in office buildings and many other kinds of nonresidential structures are occupied by large numbers of people during the day. Their bodies throw off enough heat to compensate for the heat loss through the glass and wall areas.* (The theory that nonresidential structures do not need insulation in the walls or double glazing in the windows because they are full of people, was the most novel one encountered during the researches. On this theory, if there were enough people in the building, you could pipe off the surplus Btu radiated from their bodies and operate the electric light system with them.)

6. *Any heat saved by double glazing will be dribbled away by tenant wastefulness. They will leave windows open and forget to shut outside doors.* (If there is any logic to this, it is not visible on the surface. In many buildings using double glazing the windows are fixed and cannot be opened—one way of eliminating the problem of waste. In others they can be opened, but will be so only when the rooms are *too warm* because there are too many people in them or for some other reason. In any event, there is not likely to be a noticeable effect on fuel consumption.)

So—why no insulation or double glazing in the walls of most nonresidential buildings? The only reason that makes any sense today is the unfortunately uncomplimentary one of—technological lag.

Sound-Conditioning Materials

BY PAUL J. WASHBURN*

One of the recurring problems which confront the architect is the specification of a particular type of acoustical material for a particular job. When the architect specifies an acoustical material, he is interested, primarily, in the reduction or control of sound. However, a selection based solely upon acoustical efficiency may sometimes be a needlessly expensive item. A factor that occasionally goes unheeded by the architect is that a difference in noise reduction of .05 between two materials cannot be detected by the human ear, while the cost difference might be quite significant.

As the architect knows, no one material will solve every architectural problem. For this range there are available today many acoustical materials, each with its own important characteristics. As an aid to the architect, we will summarize, generally, in this article the different kinds of materials and where they may be installed to produce the best results. Dut to the fact that so many variables are involved, such as noise coefficients, thickness, light reflection, moisture resistance, insulation value, installation, maintenance, and fire resistance, it is unfair and incorrect to say that any one type of tile is best suited for a particular type of job. Nevertheless we will try to present a comprehensive generalization as accurately as possible.

what are acoustical materials?

Acoustical materials are made from a great variety of substances and combinations of ingredients. Very efficient sound-absorbers have been made from vegetable fibers such as bagasse or wood.

Bagasse is the fiber residue of sugar cane after the juice has been extracted. Wood fibers are produced from various types of trees in the south and the northwest. Hair felt is still used, but not to the extent of former years.

Mineral fibers, such as asbestos, glass, and mineral wool, enter into many compositions, as do the vermiculite, pumice, and perlite aggregates. The binding agent can often contribute considerably to the sound absorption of a product; the porosity of materials is often increased by adding a foaming agent to the mix.

Practically all products listed and used as acoustical materials can be classified in three groups. In the order of use, they are:

1. Monolithic tiles, with or without perforations extending into the material.
2. Assembled units, consisting of perforated facings over an absorptive element.
3. Plaster compositions with acoustical properties.

The monolithic prefab tiles are by far the most widely used. For general application, this type has a number of advantages. Through adequate control of density, thickness, dimensions, and finishes during the manufacturing process, tiles with uniform absorptive characteristics and matching appearance can be produced in large quantities. Absorption capacities and characteristics are inherent in the tiles. Due to this possible precision in manufacture, their performance after installation can be relied upon to match that indicated by the standard test data on which they are rated.

Assembled units include the various combinations of sound-absorbing elements, such as rock-wool and glass-wool blankets, pads, or other materials with acoustically transparent facings, most of which are perforated. While a great many of these combinations are used in offices, some are designed primarily for broadcasting and recording studios, special music rooms, etc., where some controlled variation of sound-absorptive characteristics may be desirable. They are also used in general sound conditioning where the greatest possible sound-absorbing capacity may be required. By varying the thickness of the sound-absorbing element and the spacings between the element, the wall, and the facing, some variation in the over-all absorption and the absorption at the different frequencies can be obtained. In practically all instances today, the facings used are some form of durable, perforated panel such as metal, asbestos board, or hard board. The original use of cloth, usually muslin, has been discontinued because of difficulties and expense in maintenance.

Plaster compositions broadly include the acoustical plasters and the various kinds of "sprayed-on" materials. The plasters are built up on the wall and ceiling surfaces in the usual way. The sprayed-on types are applied by special guns. These materials are characterized by their smooth, unbroken surfaces. Their limitations lie in the indeterminate absorptive characteristics and difficult maintenance. With this type, absorption depends critically on proper application and, due to their fine surface porosity, paintability is narrowly restricted.

Practically all sound-absorbing materials owe their efficiency to the fact that they are highly porous. The absorption coefficient of a porous material depends, in a rather complicated manner, on the thickness, the size of the pores, the ratio of pore volume to total volume, and the frequency of the sound. Although it is quite difficult to evaluate all of these factors with a view to predicting the absorption ability of a material, several approximate statements may be made. In the first place, so that the pores of a material can absorb sound effectively, they must communicate with each other and with the surface of the material. Secondly, the absorption increases with the thickness, particularly at low frequencies. At high frequencies, for some materials, an increase in thickness has little or no effect on absorption. Thirdly, the absorption increases up to a certain point with the degree of porosity, as measured by the rate at which air can be forced through. For a given type of material, the lower the density, the more porosity as measured by the rate at which air can be forced through it. If the size of the pores is increased beyond a certain point, however, producing an extremely loose-textured material, the absorption decreases. Fourthly, the absorption of practically all materials is greater for high frequencies than for low frequencies.

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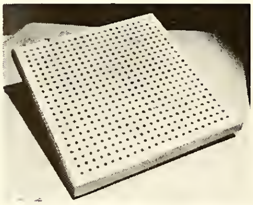
* Chairman, Technical Committee, Acoustical Materials Assn.

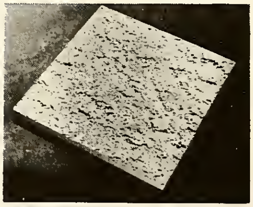
TYPES OF TILES AND THEIR CHARACTERISTICS

	cellulose-fiber tile	mineral tile
description	Most fiber tiles are made from the long, tough sugarcane fibers called bagasse, or from wood fibers. After fabrication, there are myriad minute interstices between the fibers throughout the entire tile. These tiny voids exposed by perforations give the tile its sound-absorbing qualities. All tile can be made termite-, fungi-, and dry-rot proof by special manufacturing processes.	Rock wool is the general component of mineral tiles and is felted in a manner similar to that used in the manufacture of wood fiber, but with the addition of a suitable binder. This binder is added to provide strength and toughness in the finished product. Mineral fiber tile is available with fissured surfaces or with perforated surfaces. Like the wood-fiber tile, sound is dissipated by friction in the minute interstices between the fibers, exposed by the fissures or perforations.
efficiency (noise reduction coefficient)	Most efficient at high frequencies and has a noise reduction coefficient in the range of .55 to .75.	Has high sound absorption for the middle and higher frequencies. Noise reduction coefficient, from .65 to .85.
cost	Low initial and installation cost. Varies from low to medium, depending upon method of installation.	Medium initial and installation cost.
moisture resistance	Has a moderate moisture resistance and can be used except where conditions of excess humidity prevail for long periods. Excessive moisture tends to destroy cement bond and warps most fibrous acoustical materials.	Moderate moisture resistance with safe margin for use under all normal humidity conditions. Not recommended for use in washing rooms or where it will be exposed to steam or constant high humidity.
light reflection	Has a rating of .76 to .80.	Good light reflection with a range of .78 to .84.
insulation value (thermal conductance)	Thermal conductivity ranges from about 0.30 to 0.40 Btu/hr/sq ft/in. thickness/degree F temperature difference.	Thermal conductivity ranges from about 0.40 to 0.50 Btu/hr/sq ft/in. thickness/degree F temperature difference.
fire resistance	It is a combustible tile but, when ordered with special paint finish, it is classified as slow burning.	It is classified as an incombustible tile.
maintenance	Easy to maintain, needs occasional cleaning. Can be repainted without loss of efficiency. Either oil- or water-based paints can be used and no special equipment is necessary. Brush or spray can be used.	May be cleaned with damp cloth or vacuum. Careful spray or brush painting will not affect efficiency of fissured material. Perforated material may be repainted repeatedly, without loss of efficiency, by spray or brush. Neither type should be used below wainscot height nor where subject to impact or abrasion.
installation	Can be cemented to existing surfaces, nailed or screwed to furring strips, and can be mechanically suspended.	Can be cemented to existing ceiling or mechanically suspended. Nailing is not recommended.
size	6" x 12", 12" x 12", 12" x 24", 24" x 24". Thicknesses: ½", ⅝", ¾", 1", 1¼". Butt-bevel edges, t & g edges.	12" x 12", 12" x 24". Thicknesses: ⅝", ¾", 13/16", 1". Bevel or square edges, edge-kerfed, spline-grooved.
general use	The low tile and installation costs of this material create a demand for its use, especially where a large area of ceiling space must be treated. Although it is one of the most widely used materials and can be found in almost every type of installation, commercial buildings and various types of institutional buildings are the principal users. A large variety of sizes, thicknesses, and efficiencies are available in the cellulose fiber type of acoustical tile; it is the low-price work horse of the industry.	Because of their mineral composition, these tiles will not support combustion when exposed to conventional fire-resistance tests. For this reason, they are used in theaters, restaurants, night clubs, and other places of business in which the public gathers and where fire safety requirements must be met. Fissured material is frequently used when appearance is a primary consideration. Perforated materials are used in commercial and institutional buildings and other areas requiring continued maintenance.



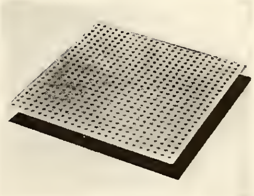
Perforated, wood-fiber tiles (as well as light-weight concrete masonry units) are the sound-absorbing materials specified for a laboratory (left).

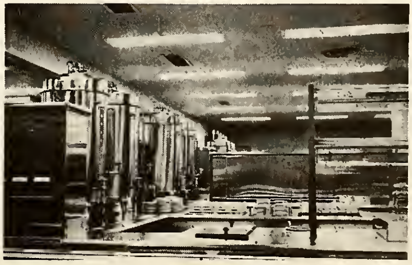
Fissured, mineral-wool tiles that will not support combustion are appropriate for an automobile display room (right). Photos: courtesy of Johns-Manville Corp., Armstrong Cork Co.



glass-fiber tile	**perforated-asbestos tile**	
In the manufacturing process of glass-fiber tile, molten glass is drawn into fine fibers under controlled techniques. When combined with a small percentage of a stable binding agent, the glass fibers are compressed and bonded into board form. The boards are then cut into tiles of desired sizes and thickness and finished to required specifications.	Perforated, asbestos-board-type tile is made of asbestos and cement and is backed with an inorganic wool acoustical backing. It is manufactured in several thicknesses and the panels are perforated with small holes to allow the sound to be absorbed by the acoustical backing.	**description**
Most efficient in the middle frequencies. Noise reduction coefficients range between .65 and .85.	Most efficient in the middle and high frequencies. Has a noise reduction coefficient between .75 and .85.	**efficiency** (noise reduction coefficient)
Medium initial and installation cost.	Medium initial and installation cost.	**cost**
Moisture resistance. Can be used in installations where varying conditions of humidity and temperature exist.	Excellent moisture resistance. Useful in places where continued high humidity and varying conditions exist.	**moisture resistance**
Has a rating of about .65 to .80.	Unpainted.	**light reflection**
Thermal conductivity about 0.24 Btu/hr/sq ft/in. thickness/degree F temperature difference.	Thermal conductivity about 0.24 Btu/hr/sq ft/in. thickness/degree F temperature difference.	**insulation value** (thermal conductance)
It is classified as an incombustible tile.	It is classified as an incombustible tile.	**fire resistance**
Can be cleaned with wallpaper cleaner or vacuum, and can be spray-painted without loss of efficiency. Tile should not be used on areas which are subject to physical abuse.	Easily cleaned and can be painted numerous times without loss of efficiency. Can be used where physical wear is present, as tiles will withstand hard usage.	**maintenance**
Can be cemented to existing ceilings and be mechanically suspended. Nails or screws not recommended.	Can be mounted on wood or applied with metal suspension system. Screwed or nailed to a framework of wood furring strips.	**installation**
12" x 12", 12" x 24"; ¾", 1" thicknesses; bevel and square edges, edge-kerfed, spline-grooved.	12" x 12", 12" x 24", 24" x 24", 24" x 48". Thicknesses: 1 3/16", 2 3/16".	**size**
Because this tile has an incombustible rating, it will be found in all types of installations that require flame resistance. Schools, public places, and offices are major users. Its good moisture resistance also permits use in places where humidity and dampness are prevalent. It is not recommended where physical wear will be encountered, such as gymnasiums or below wainscot height.	Because it does not retain moisture, it is especially useful in installations like swimming pool areas or restaurant kitchens. Its high acoustical efficiency has made it widely popular for scientific acoustical treatment in radio and television studios, concert halls, auditoriums, and in gymnasiums, music rooms, and on wall surfaces where hard wear or abuse will occur.	**general use**

Glass-fiber tiles installed on ceiling of a reception room (left) *can be cleaned with wallpaper cleaner or vacuum; should not be below wainscot height. Easily cleaned and moisture-resistant asbestos-cement tiles are an excellent choice for kitchen ceilings* (right).
Photos: courtesy of Owens-Corning Fiberglas Corp., Johns-Manville Corp.

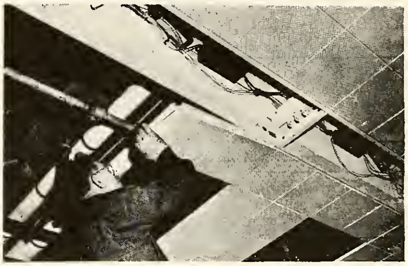


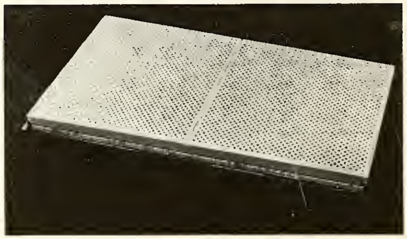


perforated-metal tile

description	The metal-type acoustical material consists of perforated metal with supporting flanges which provide structural strength, and a mineral-wool pad which absorbs sound. This tile is usually made of 26-gage steel or aluminum, with perforations to permit sound to reach the pad. It usually has a baked-on white enamel finish.
efficiency (noise reduction coefficient)	Highly efficient over entire frequency range although most efficient in low middle; has a noise reduction coefficient between .75 and .85.
cost	Generally higher initial and installation cost, compensated by high efficiency and removability features.
moisture resistance	Has moderate moisture resistance.
light reflection	Has a rating from .74 to .76.
insulation value (thermal conductance)	Thermal conductivity about 0.22 Btu/hr/sq ft/in. thickness of insulating material/degree F temperature difference.
fire resistance	It is classified as an incombustible tile.
maintenance	Easily repainted and washed; low maintenance cost.
installation	It is normally installed by mechanical fastening to furring channels or it can be fastened directly to existing ceilings.
size	Usually comes in only one size, 12" x 24", but bevel in middle gives appearance of two 12" x 12" units.
general use	The perforated, metal-type has the highest acoustical efficiency of commercial acoustical tile; however, it may also cost more than other types. It is used in installations where severe service may be encountered. As it is mechanically suspended, it can be taken down and moved to other areas. It is used quite frequently in large office and industrial plants. Office buildings use this material because it is particularly adaptable to air-conditioning systems, since special air-flow channels can be installed which allow cooled air to pass through the perforations into the room below.

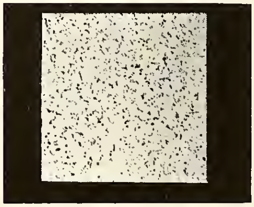
Perforated-metal tiles backed with sound-absorbing material have the highest degree of acoustical efficiency. Easily combined with other mechanical services (below), *they are especially suitable for large office areas.*
Photos: courtesy of Armstrong Cork Co.



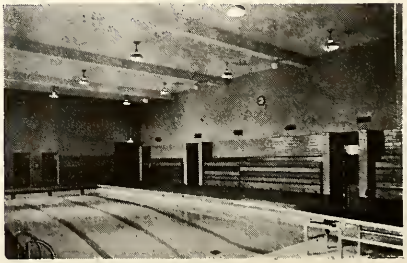


cork tile

Cork tile is made entirely from selected cork particles ground to specific particle size, baked under heat and pressure to form blocks. While cork tile has excellent insulation value and moisture resistance, its use as an acoustical tile is limited for it has lower noise reduction qualities. However, because of its resistance to extreme conditions of moisture, it is used in swimming pools, commercial kitchens, high humidity test rooms, and special manufacturing areas. Its high insulation properties make it possible to apply the tile to the top story of a building that has no roof insulation. Except in cases mentioned above, where other factors beside noise reduction are primary, its use is restricted to special type projects.



Extreme resistance to moisture favors cork tile for swimming pool ceilings (right).
Photo: courtesy of Armstrong Cork Co.



INSTALLATION OF ACOUSTICAL MATERIALS

Just as there is sometimes a best type of acoustical material for a particular job, there is usually a preferred method for applying that material. Therefore, the system of installing an acoustical ceiling should be chosen with care, as a wise choice of method will mean not only a saving in time and money but will also result in a more serviceable installation.

As each structure has its special structural problems, it will sometimes be necessary to employ different methods of attaching the acoustical tile or a combination of several methods. These methods are suggested as possibilities rather than as standard operating procedures, and are covered in the general order of their cost, from lowest to highest.

cementing

In remodeling work it is very often possible to cement acoustical tile directly to the plaster ceiling. This is the most common of all methods and usually the least expensive. The plaster, however, must be in good condition since cementing requires a smooth, solid-base surface to which the tile can be applied. Where the ceiling has been painted, tests should be made to determine if the adhesive will bond satisfactorily. The recommended test is to install a single tile, leave it in place for 48 hours, then remove it. If the paint has not softened it is considered safe to use the cement method.

nail to wood furring

Wood-furring strips, 1″ x 2″, may be used as a base for nailing or screwing the acoustical material where the ceiling surface is rough and uneven. The strips, however, should be shimmed so that they are perfectly level. In new construction, it is often possible to fur across the joists. Nailing methods have the advantage of slightly higher absorption efficiency. Building paper as a backing between the tile and the furring is used to avoid "breathing" through the joints of abutting tile.

cementing to gypsum lath

If the acoustical material is one that cannot be nailed, such as certain types of mineral wool tile, it may be best to install gypsum lath and cement the acoustical tile to it. This type of installation not only provides more rigid construction but has the added advantage of providing additional fire resistance.

screwing to gypsum board

The best method of applying a perforated, fiber tile material is accomplished by screwing the material to a base of gypsum board. The use of screws is one of the most secure methods of attaching an acoustical material.

cementing to brown coat plaster

For an acoustical ceiling requiring rigidity and a dependable fire stop, tiles can be cemented to the brown coat of plaster. This method will also reduce sound transmission through the ceiling.

mechanical suspension

Mechanical suspension systems do much to eliminate problems of ceiling design, and are adaptable to both old and new construction. They conceal overhead pipes, air-conditioning ducts, and electrical conduits, and produce a clean, modern appearance. Mechanically suspended ceilings are often used where old ceilings are too high. They are suited to receive troffer-type lighting fixtures and the extra space made available above the ceiling simplifies the installation or repair of these concealed fixtures. In addition, overall lighting in the room is often improved by a lower ceiling with good light-reflecting properties. Suspended ceilings usually do a better sound-conditioning job because the absorbent surface of the material is brought closer to the source of sound. In many cases, they make heating systems more efficient by reducing the volume of the room.

Mechanical suspension methods in old construction are likely to be more expensive because of the extra time and material necessary for each job. In new construction, however, money may be saved by eliminating plastering and other finishing. For example, ducts are concealed by the suspended ceiling for appearance.

H-runner system

There are several good ways of suspending acoustical materials mechanically. One of the most economical is the H-runner system which is rapidly erected because the materials are attached directly to the supporting members. Acoustical materials must be kerfed and back-cut to fit in the runner.

cementing to suspended gypsum board

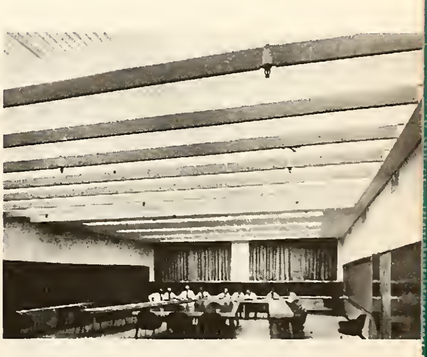
Sometimes it is desirable to suspend gypsum board as a cementing base for the acoustical material to be used. This provides a nonbreathing ceiling and additional fire resistance. In the case of suspended mineral wool materials, this is probably the most desirable system to use.

cementing to dropped plaster ceiling

The use of a dropped ceiling of brown-coat plaster and cement application of acoustical tile is approximately in the same cost range as the preceding system. This method provides a solid base, a nonbreathing ceiling, and an excellent fire stop, as well as reducing sound transmission.

metal pan suspension system

Generally speaking, the suspension of metal pan materials is more costly than other methods but it has practical advantages for many installations. Quite often it is the most efficient for acoustical sound



Combined acoustical baffles and luminous ceiling provide a high degree of hearing and seeing comfort in this conference room (above).

Photo: courtesy of F. W. Wakefield Brass Co.

reduction. This special system allows the units to be taken down individually and moved for remodeling, or for quick access to pipes, ducts, and wiring. Access doors can be eliminated in this type of construction.

acoustical baffles

In certain types of occupancies, particularly in areas containing light manufacturing operations, it is often very difficult to install the conventional type of acoustical materials. The use of acoustical baffles, suspended absorbers, or space absorbers, then becomes both economical and effective. The presence of pipes and other obstructions frequently found in rooms of light manufacturing operations would make it both difficult and expensive to install acoustical tile over the entire ceiling area. The suspended absorbers are attached by means of wires or clips. These attachments may be used at spot locations on the ceiling or to the pipes that may already be present. An important additional merit of suspended absorbers is the fact that they may be installed quickly and easily if only temporary occupancy is expected. Also, as they can be hung at any desired level, they can be located near the source of noise. Excessive air currents in a room may cause them to be set in motion unless they are well supported.

Since the sound waves reach both sides of the absorbers, the efficiency of these units is enhanced. Another type of acoustical baffle is available, combined with a fluorescent lighting fixture. It is used in commercial areas, however, and not normally in the manufacturing areas of the kind described above. The vertical ribs of sound absorption support a suspended ceiling of translucent, corrugated plastic material behind which fluorescent tubes are located.

miscellaneous products

There is a number of additional products available. Most have limited sales, although they are adaptable for specific uses. Among these are products made of pumice or similar granules which can be molded into tile or special shapes. Although these products may be called ceramic, actually they should be placed in the category of mineral tile. Hair felt, particularly when mixed with asbestos fibers for fire-retardant features, is used as a flexible duct lining and other such applications. Materials, such as glass fibers and rock wool products in both the rigid and flexible types, are conventionally used for both the inside and outside of air-conditioning ducts, to reduce the noise that otherwise would exist in air-conditioning systems. All acoustical ceiling tiles, however, are rigid in character and normally come in the conventional 12″ x 12″ size.

SUMMATION

After receiving a description of the respective sound-conditioning products available—their size, efficiencies, appearance, etc.—the architect must then select one for his particular job. The factors which govern his decision depend largely upon the type of building designed and the amount of noise expected. For example, the acoustical materials to be selected for a school building should be based largely upon their efficiency, cost, and maintenance characteristics. The more efficient materials must be used in areas that contribute most to the noise problem of the school. Corridors, for example, can carry the noise throughout the building (especially into the adjacent classrooms) unless highly efficient acoustical materials are installed. Other noise centers include typewriter rooms, band rooms, music rooms, etc.; there, too, a material of greatest efficiency must be installed. On the other hand, a ½″- or ¾″-thick material can be used in classrooms where modest absorption is desired. Thus, by using more efficient materials in the classrooms, it will be easier to keep this part of the construction within the budget. In commercial buildings, the materials that provide the greatest efficiencies, best light reflection, and ease of maintenance should be specified for general offices and typewriter rooms; the more decorative materials are used for reception rooms, executive offices, conference rooms, etc.

The effect of various mounting systems on acoustical efficiency can be obtained from each manufacturer or from the Acoustical Materials Association. If a suspended ceiling is not required, it is usually more economical to install acoustical tiles directly against the ceiling surface. If suspension is desired, the architect can take advantage of the additional 5 percent in acoustical efficiency contributed by the air space.

Acoustical tiles that are suitable for proper maintenance should always be considered. Materials that contain holes are usually the easiest to maintain over a period of years; all types of perforated tile (including perforated metal with baked-enamel finish) may be repainted repeatedly without affecting their acoustical efficiency. Where severe maintenance problems are anticipated, the situation should be discussed with the manufacturers of the respective products. Air-conditioning systems with inadequate filtering systems tend to increase acoustical ceiling maintenance problems; rooms where considerable smoking takes place must be cleaned and repainted more frequently than other types.

Acoustical tile reduces sound intensity in a room by the absorption of reflected noises. Since the ceiling constitutes the greatest reflective surface of most rooms, it is conventional to place the acoustical materials there and thus cover the greatest amount of what otherwise would be reflective areas. In small rooms containing mechanical equipment, it is frequently necessary to treat not only the ceiling but also the side-wall areas; this condition exists because the ceiling may frequently constitute only a small portion of the entire room surface and also because the noise intensity is so high. The proper amount of acoustical materials required for commercial buildings can be computed by assuming the maximum level of noise that will be caused by both people and equipment at specific locations. Changing conditions of occupancy must also be contemplated for these spaces. Careful acoustical analyses, however, are required for auditoriums, music rooms, and other places of public assembly with a fixed number of seats and specific operating conditions. An architect who has not gained sufficient experience to be his own consultant in sound-conditioning problems, must rely upon an acoustical engineer or competent acoustical consultant.

The House of Cemex

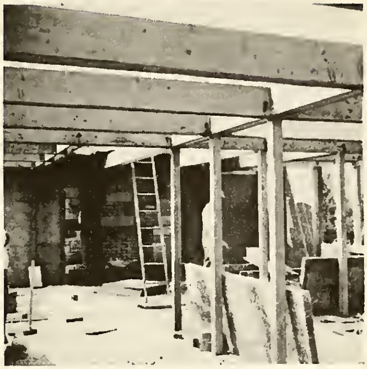


Figure 1—progress photo taken on upper level shows three 4″ x 4″ posts, spaced 48″ on center, supporting typical roof joists; note 32″ x 96″ x 4″ precast Cemex slab in foreground.

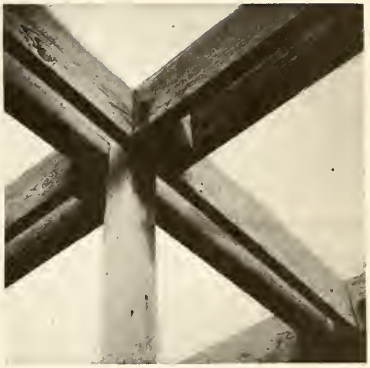


Figure 2—detail of connection at ceiling beams and column; approximately 500 split rings were used for similar connections.
Photos: courtesy of Timber Engineering Co.

Not long ago an unusual construction technique was used to advantage in a residence for S. H.MacKinnon at Quincy, Illinois. The design program for this home required that all of the more practical applications recommended for Cemex, a precast structural slab manufactured by the owner, be demonstrated in the structure. In the solution, the precast slabs were used for exterior walls, floor and roof decking, partitions, and left-in-place insulation forms for monolithic foundations and retaining walls.

The client selected R. A. D. Berwick of Vancouver, B. C., as his architect; Donald O. Hafner of Quincy, Illinois, was the associate architect.

properties of Cemex structural slabs

Cemex is a lightweight, precast concrete slab composed of chemically treated 18″ wood fibers acting as aggregate and Portland cement serving as binder. These slabs are first manufactured to a maximum size of 33″ x 97″; after curing, automatic sawing machines accurately reduced the dimensions of these units to 32″ x 96″. Although 1″, 2″, 3″, and 4″ thicknesses are currently available, the slabs can be precast to any desired thickness. This building material will not support combustion and it is practically inert with respect to expansion and contraction. It is not subject to rot or decay and because of the relatively high tensile strength present in the wood aggregate, adequate structural strength is provided. Weighing only 35 pounds per cubic foot, Cemex permits lighter structural framing members and reduces bearing loads on soil.

Three-inch thick units with ½″ cement plaster on both sides have withstood compressive test loads of 928 psi. Tensile tests on strips 2″ wide and 1″ thick have shown a strength of 500 psi. Two-inch slabs, 24″ wide and spanning 32″ have supported uniform loads of 205 psf with a center deflection of 0.436″.

The thermal conductivity as established by the Armour Research Foundation (Flat Plate Method) is:

	Density Lbs./cu. ft.
1″ — 0.555 Btu	26.7
2″ — 0.268 Btu	24.6
3″ — 0.176 Btu	24.7
4″ — 0.132 Btu	24.7

Sound absorption measurements made by the reverberation method in the Riverbank Acoustical Laboratories are partially shown below:

Test	Unit Size	Mounting	Noise Coef.
1	4′ x 8′ x 1″	1	0.50
2	4′ x 8′ x 1″	2	0.60
3	4′ x 8′ x 2″	1	0.60
4	4′ x 8′ x 2″	2	0.65

construction methods

When Cemex is applied immediately over steel joists, steel clips anchor the slabs to the top flange. If T subpurlins are specified, the slab joints are then filled with a 1:3 diluted Portland cement grout which forms a concrete wedge in the point below the bulb of the T; this method provides anchorage without the need of clips. When Cemex is used as decking over wood joist or rafters, it is simply spiked to the wood members. As this material has no directional grain and is not brittle, there is no danger of splitting or cracking. In wall construction, a bottom plate is not required as this slab is a concrete product and can be placed on concrete foundation walls with cement mortar. The low density of this product does not afford good nail-holding qualities, however, and a top plate must be attached to the top of a Cemex wall by means of lag screws long enough to penetrate approximately 5″ into the vertical wall. To attach other materials to the wall faces of this type of slab, several commercial bonds have proven highly satisfactory; occasionally, wing nuts or speed fasteners are also used to provide assurance of good anchorage.

As its open-textured composition is not effective as a barrier against driving rains and winds, Cemex should never remain unsurfaced on the exterior. High humidities present no condensate problems for structures possessing a roof decking of this material. The manufacturer states that no reports have ever been

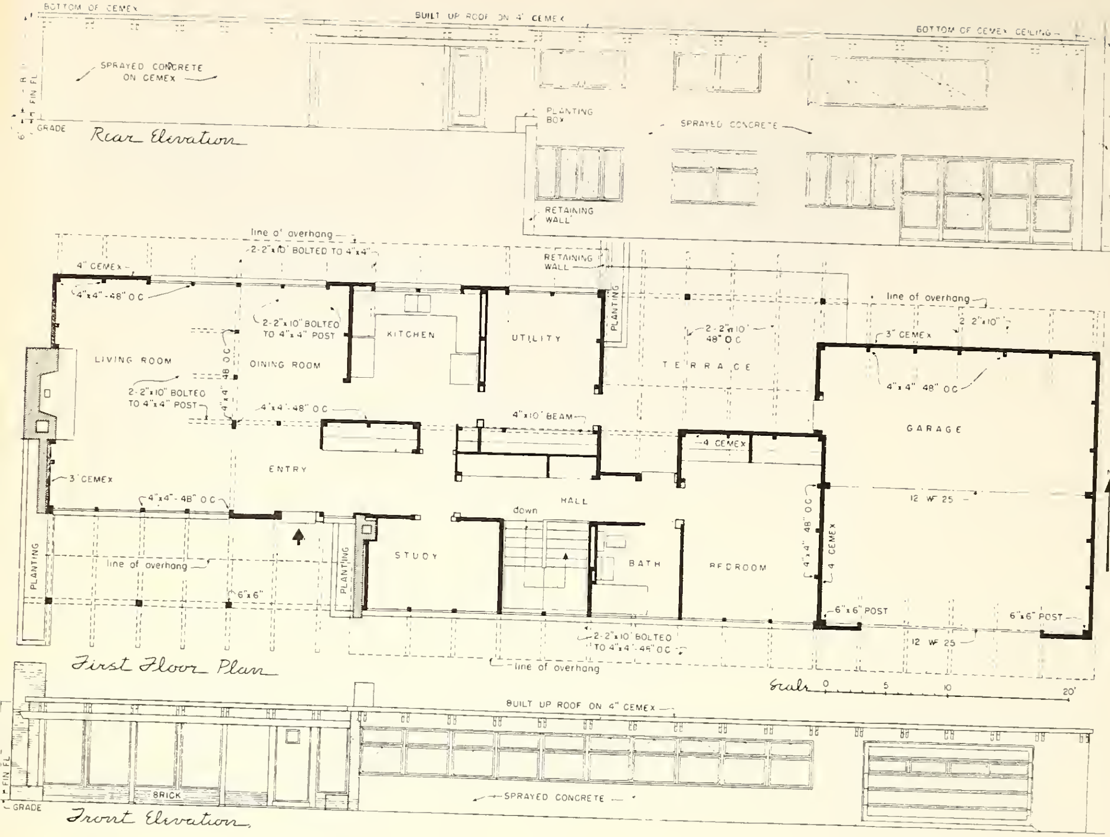


Figure 3—plan of upper level and principal elevations.

received indicating that absorption by the open-textured ceiling resulted in condensation and a dropping back of accumulated moisture. On such occasions, the strength of the slab is substantially improved rather than weakened by frequent exposure to moisture.

A slab with an 1/8" asbestos cement sheeting bonded to one side renders a Cemex slab satisfactory for curtain-wall construction in industrial buildings and low-cost housing projects. Exterior applications, however, are generally surfaced with Portland-cement stucco, any one of several types of sprayed concrete, or conventional types of horizontal and vertical siding. An air pressure of 85 lbs. is normally required to blast stucco on an existing wall. Whether stucco, sprayed concrete, or hand-trowelled plaster is applied to these slabs, it is recommended that a strip of diamond-key plaster mesh be placed over the joints of the slabs. A 3" strip will reinforce the open crevice and prevent hair cracks after curing. In most instances, the amount of concrete sprayed on an exterior surface need not increase the slab thickness by more than 1/4". For all applications of Portland-cement sand finish, the manufacturers recommendations prohibit the use of hydrated lime of the usual 10 percent ratio.

Because of the deep surface interstices, it is not feasible to brush-paint Cemex; spraying is recommended and either water or oil-base paint is suitable. Even though an interior wall may have been spray-painted many times, an ultimate desire for a plaster finish presents no problem, as the open porosity will still furnish an excellent plaster key without need of lathing or mesh.

analysis of MacKinnon residence

Facing the southwest, the distant view for this location, the front elevation presents an appearance of a single-story structure (*Figure 3*). The rear, double elevation faces the northeast and a background of trees which affords valuable weather protection. The plan is based upon a 4' module which has proved to be entirely satisfactory from the viewpoint of the owner. Vertical 4″ x 4″ posts, spaced 48″ on center (*plan Figure 3*), are dowelled into ½″ diameter bolts projecting from the foundation walls; for reasons previously discussed, there was no need for wood bottom plates. Floor and roof joists are anchored to the tops of posts by means of 2½″ diameter Teco rings (*assembly detail in Figures 1 and 2*). A single ½″ carriage bolt occurs at each juncture of post and joists. The living room floor, which is also the ceiling of the recreation room below, is supported by open-web steel joists spaced 24″ on center. The balance of the floor joists over the excavated portion of the house are 2″ x 10″ members which are also spaced at 24″ intervals. Over all floor joists, a 3″ decking of Cemex is faced topside with a ¾″ cement traffic surface. The decking is anchored to the steel joists with steel clips and to the wood joists with 20d spikes (*Figure 4*).

A completely flat roof deck disperses rain water in every direction; with such an even distribution over the roof perimeter it was possible to eliminate gutters and downspouts. All roof decks and exterior walls are anchored with 40d spikes and tin roofing caps.

The 2′-8″ x 8′-0″ slabs which form the exterior walls are laid up perpendicular to the structural posts; each spans two bays of the 4′ module. The three courses of structural slabs, which are spiked to posts and act as bracing, provide an 8′ ceiling height. To assure maximum bracing strength, the vertical joints are staggered on respective posts. The east, south, and west walls of the lower elevation are monolithic retaining walls with integral waterproofing; 2″ Cemex slabs were employed as interior form lining.

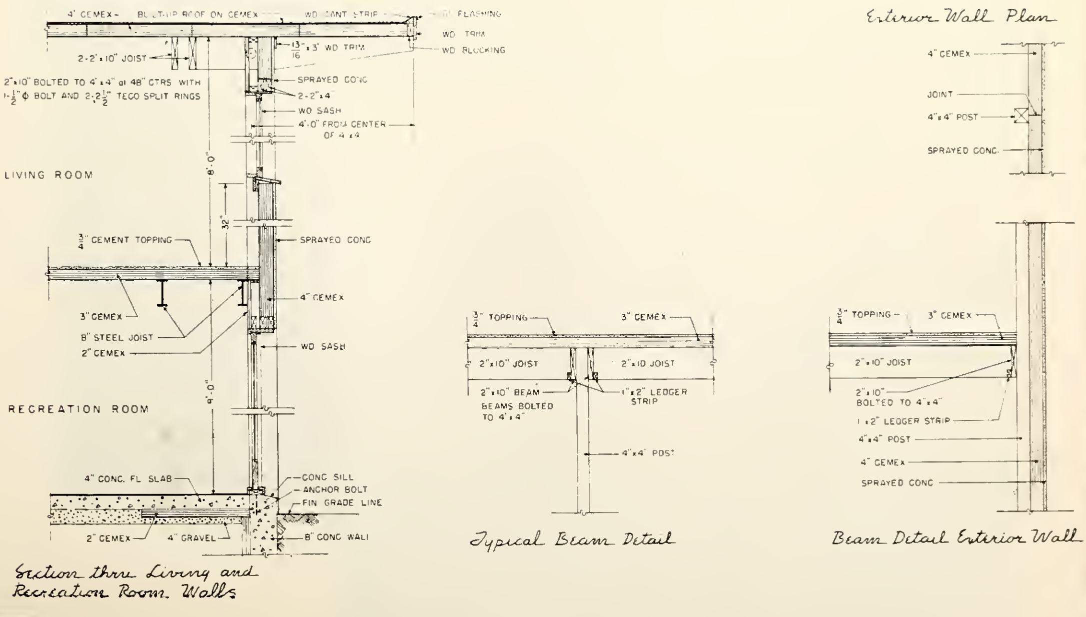
Plaster was not included in the schedule of interior finishes; all structural members remain exposed. Joists and vertical posts were sanded and painted. Although the interior wall surfaces were spray-painted, they might have been left in the natural gray cement color if the designer had so desired. Bathrooms are surfaced with precast slabs that have an asbestos cement facing on the interior surface, which provided a suitable base for papering.

The entrance hall, living room and dining room have cork-tile floor surfacing while the kitchen, study, and master bedroom floors are asphalt tile. The recreation room floor and hallway floor of the lower level are concrete with integral green coloring. The finished roofing is tar and gravel, the latter being white stone gravel which assists summer heat deflection.

Radiant baseboard panels are recessed between the vertical 4″ x 4″ posts and against the inner surface of the Cemex panels. The radiant panels are joined by ½″ pipes passing through holes drilled in the vertical posts. An oil-fired furnace is located on the lower level along with other mechanical equipment.

It is estimated that conventional construction costs for a residence of this size would approximate $50,000. The cost of this structure, which was completed in four months time, was less than $25,000.

Figure 4—wall section and typical details.



Home Acoustic Treatment

BY MICHAEL RETTINGER

Some architects seem to harbor the idea that acoustical materials are used to decided advantage only in motion picture theaters, broadcasting stations, and modern offices. Certainly such enclosures are practically always treated acoustically, and would suffer noticeably in their performance characteristics if they were not so treated. On the other hand, residences receive but a sparing—if any—amount of acoustic consideration, and even music rooms in the home are frequently "treated" only with carpets, tapestry, or upholstered furniture. The reasons for such a disregard in the provision of good hearing conditions in the home are not directly obvious, since it certainly stands to reason that comfort in the home is no less important than comfort at the theater or the office. There appears to be a desirable field for study in this direction.

Possibly one reason why acoustic materials are not used more frequently in the home is that they appear to afford limited comfort. It is thought that in a quiet residential section there is no need for noise-reducing treatment within the house. However, there exists a decided satisfaction when such materials are applied in the kitchen, dining, and living room. The clatter of dishes, footfalls, the moving of chairs, children's cries, etc., when reduced by even as much as 3 decibels—and 6 decibels can be realized frequently in practice—has a markedly soothing effect on our highly sensitive auditory nerves.

There is still another comfort which acoustic materials afford in a small room. Made porous, such materials are invariably good heat insulators, and as such give a feeling of warmth to a room. Body radiations are strongly reflected by such treated walls, and a person seated in a small room, even when it is

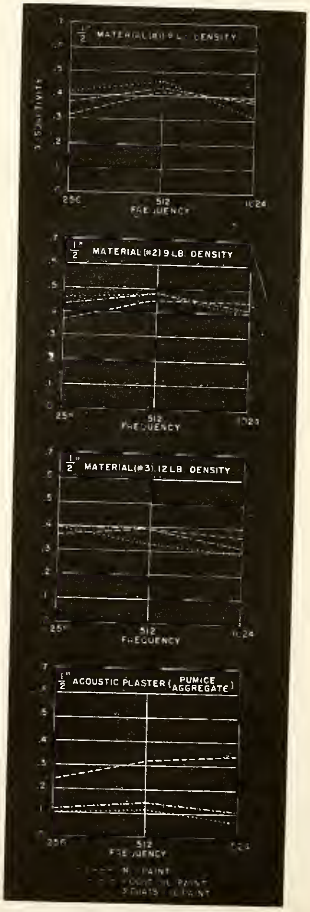


Figure 1

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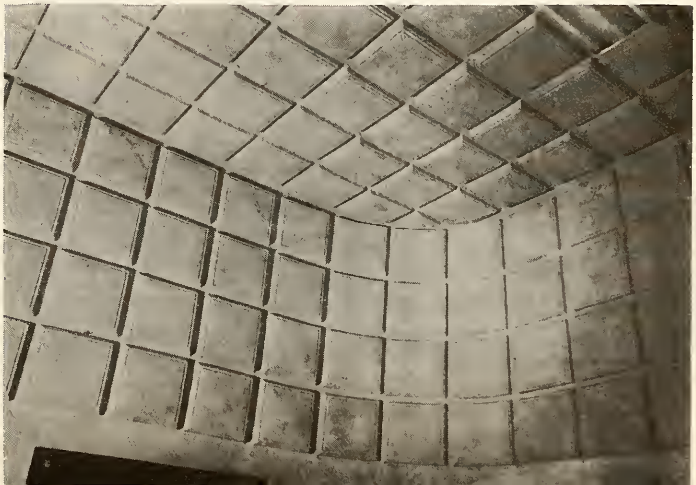
*Consultant on Acoustics, Encino, Calif.

not heated, has a feeling of warmth and comfort.

Perhaps another reason why sound-absorbent materials have not found their way into homes more frequently lies in the question of how successfully such materials can be painted without destroying their absorptivity. In the home it frequently is desired to change the appearance of a sound-absorbent material, either for the purpose of increasing its light-reflection coefficient or to enhance the finish. A number of acoustic materials are prepainted by the manufacturer, while the application notices of others warn not to apply paint to the material. The writer has made a number of tests on different acoustic products to determine the effect of painting. Figure 1 shows the effect on four materials, the absorptivity of each of which first was measured unpainted, and then, measured again after one coat of oil-paint had been applied with a spray-gun, and finally, after three such coats had been applied. Materials 1, 2, and 3 were *soft*, ½″ thick, and had densities of 6, 9, and 12 lbs. per cu. ft. respectively. Material 4 was ½″ acoustic plaster of the pumice aggregate type; that is, it was hard and porous. Figure 1 shows that the light-density acoustic tile suffered, through painting, in the frequency range considered, no reduction in its absorptivity, and, indeed, experienced a considerable increase at 256 cycles. The materials of 9 and 12 lbs. density likewise were not greatly affected by painting, except perhaps material 3 at 1024 cycles. But ½″ *hard* acoustic plaster became, through painting, practically useless as a sound absorbent. For this reason, the tests *tend* to show that soft, fibrous, low-density materials can be painted without greatly suffering a

Cemex Acoustical Panels inserted between exposed ceiling rafters and held in place with quarter round trim. Panels left in natural gray cement color to blend with color of stone wall construction. 1 in.-thick units consist of long wood fibers chemically treated, coated with Portland cement binder, and compressed while in a plastic state. Manufactured by The Cemex Corporation.



Diaphragmatic tiles, on ceiling and walls, absorb sound by resonant vibration of their surfaces. Each featherweight unit, 1 sq. ft. in size, weighs only 3 oz. The tiles are fireproof, have low maintenance cost, and may be applied to any surface. *Acoustic Diaphragm Tile*, Heerwagen Acoustic Decoration Company.

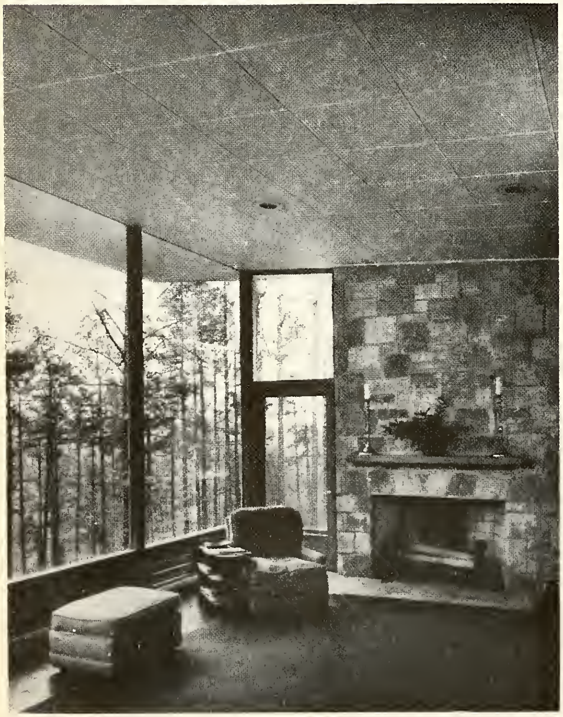
Formed of processed mineral filaments, the lightweight acoustical tile on this ceiling has irregularly shaped sound-catching fissures. Tile size is 12" x 12", weight 1½ lbs. per sq. ft., and noise reduction coefficient is up to .70. It is applied with adhesives. *Motif'd Acoustone,* United States Gypsum Company.
Photo: Hedrich-Blessing Studio

reduction in sound-absorption efficiency, while hard, porous materials cannot.

The above concerned itself with unperforated material. There are, of course, a number of perforated products on the market which, although not soft, can be painted any number of times without destroying their absorptivity. These tiles can be had in both combustible and incombustible material, the latter frequently being slightly more expensive.

Acoustic tiles come in a variety of shapes and materials. To use a very broad classification, they may be said to be of two types—flexible and inflexible. Flexible tiles, which comprise such materials as hair-felt, eel-grass, rubber, cork, etc., owe their absorbing power to the conversion of sound energy into mechanical energy by flexural yielding as well as to the conversion of sound energy into heat through the frictional resistance offered by the interconnecting pores or channels within the material. Inflexible tiles, which are, in general porous products of a ceramic nature, absorb largely through the conversion of sound energy into heat by friction, the absorption caused by flexural yielding being negligibly small unless the tile is very thin and mounted so as to introduce an air-space between the tile and the backing wall. It is true that a material such as a pane of glass or a wood panel may convert very little sound energy into heat and yet deaden certain frequencies highly by vibrating in resonance with the exciting tone, but one can hardly classify such materials as acoustic tiles in the common sense.

Light acoustic tiles usually have higher absorptivity when mounted on wood furring. An air-space between the acoustic tile and the backing wall increases the absorption by permitting tile vibration and interreflection of sound in the hiatus. While such a method of application appears more compli-



Ceiling panels used in this home are termite-, fungi-, and dry rot-proof. They are fire resistant, possess a low thermal conductivity, and maintain sound absorption when painted. Normal brush painting will not bridge or close perforations. Available in two standard sizes, 12" x 12" and 12" x 24", in ½", ¾", and 1¼" thicknesses. *Acousti Celotex,* Celotex Corporation.

Fissured cork acoustical tile is used on this ceiling. Lightweight, 1½" thick; can be repainted without loss of acoustical efficiency. Resin-emulsion white paint creates a glareless white surface that reflects high percentage of light. *Corkoustic*, Armstrong Cork Company.

cated, it may actually be less expensive, if the increase of absorption due to the air-space is great enough, while in addition it may provide a higher transmission loss. This increase in absorption through interreflection amounts in some cases to as much as 40 percent between a frequency range more than two octaves wide.

Next to the method of application, the thickness of the material should be taken into consideration. For example, a layer of hair-felt, if 45 percent absorptive at a certain frequency, will not be 90 percent absorptive when the thickness is doubled, but will be less than 90 percent. Indeed, instead of increasing the thickness of the tile, it may in some cases be less expensive to treat a larger area with a thinner tile.

While ceramic tiles have proved to be highly efficient sound-absorbing materials in banks and offices, where the noise is due mostly to the high-frequency sounds emitted by the typewriters and office machines, they may not always be suited for acoustical treatment in homes, where a high degree of absorption is often required for the low frequencies. The small interconnecting pores of many ceramic tiles are efficiently absorbent only for sounds of short wave-length, that is, for high frequencies. In such cases it is advisable to employ *flexible* tiles which provide supplementary absorption by flexural yielding when struck by sound waves of low frequency.

One noteworthy merit of a tile, in contradistinction to an acoustic plaster, consists in its *incorporate* absorptive value. Since tiles are cut or cast in a factory under controlled conditions, their porosity, and hence their absorptivity, can be made alike; this feature is not always easy to duplicate when the material has to be mixed at the place of installation. Moreover, since in a factory methods of production can be employed which would be infeasible anywhere else, tiles usually have a higher absorption coefficient and greater structural strength than plasters.

A word of caution again should be added, however, in regard to the *absorption coefficient* of a material. The term *absorption coefficient* represents the fractional amount of incident sound energy which is purely absorbed, that is, which is converted into heat or mechanical energy or both. Some of the energy which enters the material is also transmitted and, in a house, can enter an abutting room where it may act disturbingly. Therefore, materials with a high *absorption coefficient* which at the same time have a high transmission coefficient may, from an all-around efficiency standpoint, be actually inferior to products having a lower absorption coefficient but having at the same time a negligibly small transmission coefficient. It may not be good design to quiet the kitchen room while permitting the dining room to become noisy. It is important, therefore, to consider carefully the conditions under which the acoustic material was tested—whether it had a rigid backing, whether it was placed on furring strips, etc.

If the residential designer takes into consideration the quality as well as the quantity of the sound to be treated, and studies carefully the characteristics of the materials that are available, he will find that it is possible to create an acoustical environment in the home that is more satisfactory than that normally provided. The various products on the market have their particular uses, and it is as foolish to misuse them as it is to ignore them.

PLASTICS MOVE IN

Among the newest materials to be used in building construction, vinyl, acrylic, and polyester plastics in various forms are increasingly being specified for floor and wall covering, panels and partitions, glazing, luminous ceilings, skylights, store fronts, wire and cable insulation, surface coatings, flashing, furniture covering, fabrics and many other uses. Sprayed-on vinyl plastic, because of its ease of application at awkward contiguous intersections, may eventually revolutionize many construction methods that are standard practice today. Roofing and flashing are but two such possibilities. In most instances, sprayed-on plastic applications are now competitive with more conventional materials and methods. Happily, there is every reason to think that substantial economies can be realized in the future by inventive uses of this material. This new concept of surface covering was recently applied to 39 interior columns in the lobby of the UN General Assembly Building, New York. As more than 3000 visitors pass through this building on an average day, the problem of keeping the columns free of finger and scuff marks was a major one. As paint was ruled out, the considered materials were sprayed plastic and cemented-on vinyl plastic sheeting. Plastic spray won out because of its better adaption to the shape of the columns, absence of joints, exact color matching, and its lower price. A total of over 5000 sq ft was covered at an average cost of only $0.45 per sq ft.* Employing only three men for the entire job, it took but 10 days to spray an average thickness of 1/50 in. Unlike a paint spraying operation, plastic-spray technique requires neither drop cloths for floor protection nor respiratory masks for spray-gun operators. In this way, the lobby remained open to the public during the entire operation. During the erection of the 525 William Penn Place Building, Pittsburgh (*page 15*), a sprayed plastic coating protected the 3300 stainless-steel spandrel assemblies from abrasion during shipment and erection. This protective coating was easily peeled off after completion of the building.

**Cost data from Progressive Industries, Inc., Long Island City, N. Y.*

Sprayed-on Vinyl-Plastic Sheeting

BY GUY G. ROTHENSTEIN*

Operation Mothball: early use of plastic spray

Sprayed-on vinyl-plastic sheetings are obtained by spraying a liquid vinyl chloride-acetate copolymer (for simplification, hereafter called plastic spray), using standard spray equipment capable of producing 90 lbs. of air pressure and 25 cfm air displacement.

characteristics

If such a material is applied by six to eight passes of the spray gun over any polished surface (without adhesive), it can be stripped off after a few hours of curing. A flexible plastic sheeting is formed, having the general properties described *(Table of Characteristics)*.

An additional characteristic of this material is that it can web over open spaces up to 2″ wide, and if mixed with a webbing solution the distance it spans can be increased, up to 24″. Mention of this "webbing" recalls one of the original applications of plastic spray, namely, the weather protecting of the U. S. Government equipment, often referred to as Operation Mothball. From as early as 1942, guns, airplanes, and large parts of vessels have been "wrapped in cocoon" and then remained outdoors for years without being harmed in any way by the elements.

It is amazing that the government spent an estimated $40 millions on vinyl-plastic-spray materials and applications, before the building industry became interested. It may be questioned whether this was due to a poor public relations policy on the part of the manufacturers, or to a lack of imagination by those members of the building trade acquainted with this product in its early stage. This material, originating as a chemical development outside of the building industry, was considered by its formulators for several years mainly a maintenance product. Imitating more or less the government applications, it was first used for packaging industrial equipment for outdoor storage or overseas shipment; then for repair and rehabilitation work on existing structures. Roofs and stucco, brick, and concrete walls were successfully covered with plastic spray. A good number of these applications were made in Florida and in the Midwest. After some time, the material was also applied to some new structures as a weatherproofing material as well as an interior wall covering. An important early use, developed in 1948 by the Department of Agriculture was for sealing tobacco warehouses during the fumigation process. Through all these various applications, members of the architectural profession became, little by little, acquainted with plastic-spray materials and aware of the tremendous potentialities for new construction.

The revolutionary aspect is that here is a durable material which can be applied by simple means on surfaces of any kind, size, and shape, to form a flexible, continuous, jointless "skin," not affected by movements of the structure. Furthermore, this "skin," of leatherlike texture, has an attractive appearance and comes in a large range of colors.

One of the main struggles throughout the history of building construction has been man's effort to master the technique of joining materials. Sprayed-on-plastic sheeting is one of the greatest factors for progress in the struggle, to date. Actually, the construction of the joint between structural materials becomes in many respects secondary, because the sheeting covering the joint will now perform vital functions which previously had to be engineered, often at great expense, within the materials.

Other unique features of sprayed-on-vinyl sheeting are that it is adaptable to three dimensional shapes and that there are no limitations as to size. A convex dome, several hundred feet in diameter, can be as easily covered as a concave bowl a few inches in diameter.

longevity

For all building materials, the question of length of life is very important. Resins used to formulate these materials are completely polymerized and the sheeting is formed only by the evaporation of solvent; no embrittlement or shrinkage is experienced with the aging of the material. Unpigmented vinyl, however, should not be exposed to the rays of the sun. The materials should always be pigmented with aluminum, vinyl-plastic dispersions in colors, or both. If used for weather protection, it is important to specify the material in sufficient thickness. Generally, horizontal exterior surfaces are more exposed than vertical ones; therefore, the recommended thickness for a horizontal exterior surface is at least 30 mils.

The writer has examined sheetings that had been exposed for eight years: they did not show any sign of wear or deterioration. Accelerated weather tests indicate actually a much longer life span for these materials. It may therefore be considered a conservative conclusion that plastic spray will still be in good condition after 8 to 10 years of outdoor exposure and 12 to 15 years of indoor use.

After such periods of time, it is advisable to spray an additional 10 to 15 mils on the original sheeting. The plasticizer contained in this material will partially penetrate the old material and has the tendency to reactivate it. This rejuvenation process may be repeated during the normal life span of a building. (Contrary to paint, the strength of vinyl-plastic sheeting increases as its thickness is built up.)

Another suggested means to co-ordinate the life span of sprayed-on vinyl-plastic sheeting with the life span of structures is to apply mastics or vinyl-based paints as top coatings, then to replace this top coat when required.

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* *Designer, New York, N. Y.*

new concepts

If the concept of a "continuous skin" over structures is fully analyzed, it has the greatest repercussions on the selection of the other materials going into the structure, and their methods of erection.

Facts: Materials classified for "interior use only" may now be used for exterior wall construction as well. Precast elements, building panels, or boards may be erected with butt joints. Such units may be held in place by means of countersunk nails, screws, or bolts which will not be visible through the surface of sprayed-on vinyl-plastic sheeting.

Examples: In frame construction, the materials used on the outside of the wall may be simply plaster, ordinary plywood, or boards of gypsum, fiber, or cement asbestos.

In fireproof construction, columns, spandrels, or concrete masonry no longer require the application of heavy and expensive brick, stone, or metal facings.

In load-bearing wall construction, walls built of cinder or concrete block faced with plastic spray are attractive and absolutely waterproof.

Canopies, balconies, and other projections of buildings, as well as fascias and soffits, can now be covered with the same "continuous skin" as the vertical surfaces.

Roofs (except for load requirements) may be built in the same manner as walls. Projections such as upset beams, skylights, etc., do not pose any flashing or waterproofing problems.

exterior surfaces

From an economic viewpoint, the greatest interest lies in the use of sprayed-on vinyl-plastic sheeting as a facing material for the outer face of exterior walls of multistory structures of fireproof construction.

In general, the most common method for this type of construction consists of a skeleton of fireproofed steel or reinforced concrete, filled in with back-up masonry and windows; columns, spandrels, and masonry are then faced with a more expensive type of brick or other masonry materials. This "masonry curtain," supported by shelf angles, is expensive and its weight adds further cost to the skeleton and its foundations. The windows set in the openings are calked for weatherproofing. Even though this type of construction is referred to as "permanent," experience shows that repairs and maintenance are needed over the years; the windows have to be recalked, joints repointed, and the entire façade steam-cleaned.

If the realities of maintenance for any type of wall are recognized, tremendous savings in construction cost result when the "curtain" of masonry materials is omitted and replaced by vinyl-plastic sheeting sprayed on columns, spandrels, and back-up masonry. This original covering will stand up for at least 8 to 10 years; after that time it will have to be sprayed again as part of the regular building maintenance. In evaluating the savings, it should be considered that the cost of concrete and back-up masonry for a plastic-sprayed wall will be slightly higher because of desirable higher standards of workmanship. Besides the omission of the masonry curtain, however, savings will result through the absence of calking and additional materials for sills (the plastic spray seals the joint between window and structure).

Buildings faced with sprayed-on plastic sheeting are of monolithic texture and are washable. They can be practically any color and can do wonders to break up the monotonous appearance of our cities. (This point should be of special interest to housing authorities and builders of large developments.)

The same principle of exterior "plastic skin" can be applied to nonfireproof construction by substituting more economical materials and methods of assembling "under the skin."

Sprayed-on plastic sheeting also forms excellent roofs; however, for a roof of conventional design, there seems to be no particular saving unless special problems, such as unusual movements of the structure or upset beams, skylights or openings requiring flashings and counterflashings, are present which would increase the cost of conventional roofing or make its use impractical.

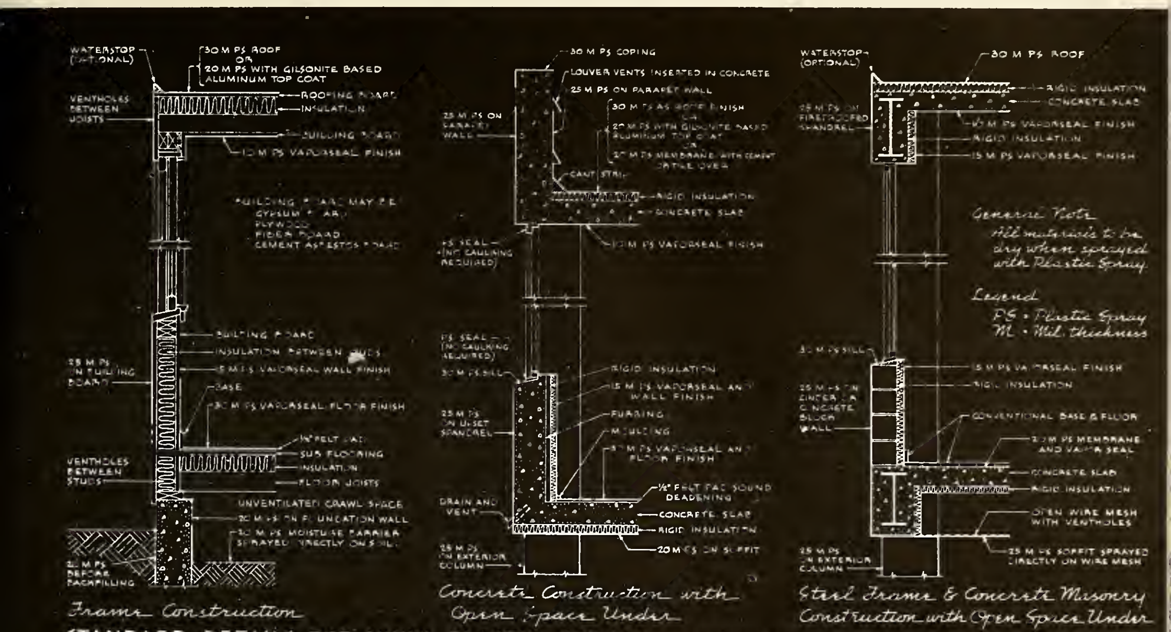
interior wall surfaces

Of equal importance to the new method of construction of walls and roofs are the interior uses of sprayed-on vinyl-plastic sheeting which bring about a completely new concept of finishes.

In geographical areas where winter heating is required, walls covered on the outside with a plastic spray "continuous skin" should also receive an interior vapor seal. This is necessary to prevent the vapors captured inside the structure from attacking the insulation and wall materials. The conventional vapor seals usually placed inside the wall have the disadvantage of leaving the wall finish exposed to attacks by vapors. If, instead, plastic

CHARACTERISTICS OF SPRAYED-ON VINYL-PLASTIC SHEETING

Thickness (6 to 8 passes):	.035"
Weight:	2 oz. per sq. ft.
Adhesion:	On glass: up to 25 psi On porous materials: nonstrippable
Tensile strength:	1200 to 1400 psi
Elongation:	200 to 225 percent
Flexibility:	+ 60F to + 100F: 500,000 flexes —32F: can be bent 180° over a ⅜" mandrel
Color:	Natural: ivory, gray, opaque. Pigmented with aluminum: metallic grey. Pigmented with dispersions: all colors
Texture:	Smooth with leatherlike grain
Abrasion:	Loss of 75 mgm after 5000 revolutions of Taber abraser
Wear:	Loss of .001" after 1000 revolutions of Taber abraser
Longevity (pigmented):	Exterior: 8 to 10 yrs Interior: 12 to 15 yrs
Temperature range:	— 40F to + 180F
Fire resistance:	Self extinguishing, does not support combustion
Corrosiveness:	Causes no corrosion on plain low-carbon steel when exposed to an atmosphere of 95% humidity at 95F (± 3F) for 240 hrs
Vapor transmission rate:	Not more than 0.5 gram per 100 sq. in. per 24 hrs
Chemical resistance:	Not affected by acids, petroleum solvents, aromatic gasolines, alkalis, aliphatic hydro carbons, oils, fats, grease, and salt spray
Bacteriostatic and fungistatic resistance:	Not affected by major mildew and mold groups
Radioactive resistance:	Reduces the penetration of radioactive radiation into the surface to which it is applied


WATERSTOP (OPTIONAL)
30 M PS ROOF OR 20 M PS WITH GILSONITE BASED ALUMINUM TOP COAT
VENTHOLES BETWEEN JOISTS
ROOFING BOARD
INSULATION
BUILDING BOARD
10 M PS VAPORSEAL FINISH
BUILDING BOARD MAY BE: GYPSUM BOARD PLYWOOD FIBER BOARD CEMENT ASBESTOS BOARD
BUILDING BOARD
INSULATION BETWEEN STUDS
25 M PS ON BUILDING BOARD
15 M PS VAPORSEAL WALL FINISH
BASE
30 M PS VAPORSEAL FLOOR FINISH
½" FELT PAD
SUB FLOORING
VENTHOLES BETWEEN STUDS
INSULATION
FLOOR JOISTS
UNVENTILATED CRAWL SPACE
20 M PS ON FOUNDATION WALL
30 M PS MOISTURE BARRIER SPRAYED DIRECTLY ON SOIL
20 M PS BEFORE BACKFILLING
Frame Construction
30 M PS COPING
LOUVER VENTS INSERTED IN CONCRETE
25 M PS ON PARAPET WALL
25 M PS ON PARAPET WALL
30 M PS AS ROOF FINISH OR 20 M PS WITH GILSONITE BASED ALUMINUM TOP COAT OR 20 M PS MEMBRANE WITH CEMENTTOPPING OVER
CANT STRIP
RIGID INSULATION
CONCRETE SLAB
PS SEAL (NO CAULKING REQUIRED)
10 M PS VAPORSEAL FINISH
PS SEAL (NO CAULKING REQUIRED)
30 M PS SILL
RIGID INSULATION
15 M PS VAPORSEAL AND WALL FINISH
25 M PS ON UPSET SPANDREL
FURRING
MOULDING
30 M PS VAPORSEAL AND FLOOR FINISH
½" FELT PAD SOUND DEADENING
DRAIN AND VENT
CONCRETE SLAB
RIGID INSULATION
25 M PS ON EXTERIOR COLUMN
20 M PS ON SOFFIT
Concrete Construction with Open Space Under
WATERSTOP (OPTIONAL)
30 M PS ROOF
RIGID INSULATION
CONCRETE SLAB
25 M PS ON FIREPROOFED SPANDREL
10 M PS VAPORSEAL FINISH
RIGID INSULATION
15 M PS VAPORSEAL FINISH
General Note
All materials to be dry when sprayed with Plastic Spray
Legend
PS = Plastic Spray
M = Mil. thickness
30 M PS SILL
15 M PS VAPORSEAL FINISH
RIGID INSULATION
25 M PS ON CINDER OR CONCRETE BLOCK WALL
CONVENTIONAL BASE & FLOOR
20 M PS MEMBRANE AND VAPOR SEAL
CONCRETE SLAB
RIGID INSULATION
OPEN WIRE MESH WITH VENTHOLES
25 M PS ON EXTERIOR COLUMN
25 M PS SOFFIT SPRAYED DIRECTLY ON WIRE MESH
Steel Frame & Concrete Masonry Construction with Open Space Under

STANDARD DETAILS FOR VINYL PLASTIC SPRAY (COURTESY OF PROGRESSIVE INDUSTRIES, INC., LONG ISLAND CITY, N.Y.)

spray is applied to the interior surface of the wall, it forms a vapor seal at the ideal location and becomes at the same time a decorative finish, not vulnerable to vapors.

For structures that are air cooled during the summer, the "continuous skin" vapor seal on both surfaces of the exterior wall is also highly desirable.

Besides the usefulness of plastic spray as a vapor seal, this material makes a highly desirable interior wall finish, the use of which should not be restricted to the inside of exterior walls. It may be used wherever it is desirable to have a finish of better wearing qualities than paint or wallpaper. Pigmented with color-fast vinyl-plastic dispersions and sprayed on in thicknesses varying from 10 to 30 mils, plastic spray forms a jointless sheeting of attractive appearance, in performance very similar to the well known and widely used calendered vinyl-plastic sheetings which are cemented to walls. The most obvious advantage of the sprayed-on vinyl-plastic wall covering is the complete absence of joints and a better bond to the surface. Another advantage is that three-dimensional shapes can be covered without difficulty.

Mostly because of the simplified installation process, the plastic-spray wall coverings are considerably lower in cost than comparable cemented-on types.

In instances where the maintenance budget of a building is considered while selecting wall finishes, this new material will, over a period of years, actually produce considerable savings over paint. This fact is little by little being recognized by building owners. For instance, the New York Waldorf-Astoria Hotel has used plastic spray for a number of bathroom walls and ceilings, and one of the Henry Hudson hotels has made an even more extensive use of this material. Other significant applications are in the elevator lobbies of the new Lever House and the Knoll Associates New York showroom, as well as in various public areas of the new Trade Bank and Trust Company, also in New York.

The plastic spray is a logical sanitary finish for areas subjected to hard wear and undoubtedly it will be used widely in schools, hospitals, hotels, ships, public areas of apartment houses, and, to some extent, in homes. Considerable interest has been shown by architects already acquainted with this material, in its application on cinder or concrete block and on lightweight masonry materials such as precast wood-fiber cement panels, etc., in order to save plastering and painting and yet obtain smooth, washable surfaces. With some care to the treatment of the joints, practical and handsome surfaces may be obtained in this manner. When applied on plaster, the finish coat of plaster can be omitted, which results in further savings.

new architectural details

Besides the use of these new materials to cover entire exterior and interior building surfaces, there are numerous smaller applications where the combined characteristics of vinyl-plastic sheeting and its spray application permit the development of simplified architectural details. This technique stays entirely within the concept of conventional construction.

Membrane waterproofings, flashings, copings, and corrosion-protection of metals can be done advantageously by the plastic-spray method. The plastic-spray gun will become a commonly used tool on construction jobs, and will eliminate the need for many expensive and elaborate details, saving considerable drafting and specification time for the architect.

prefabrication

Poor solutions of joint engineering have caused many systems of prefabrication to fail. The entirely new concept of waterproofing and vaporproofing joints on the surface, brought about by plastic spray, has most interesting possibilities for prefabricated civilian and military structures.

One system designed by the writer consists of shop-finishing panels with plastic spray, then coating the specially designed joint in the field by a simple vinyl-plastic application—it can even be applied by brush. Shop and field coats will fuse together to form a flexible "continuous skin."

industrial construction, mechanical work

In view of the excellent protection which vinyl-plastic provides against corrosion of any sort, the spray application of this material is of greatest interest to industries with either high humidity conditions (bakeries, dairies, laundries, etc.) or problems of acids, alkalis, salt spray, etc. Interiors, exteriors, ducts, hoods, tanks, and miscellaneous equipment may be lined with plastic spray. In New York's new Lever House, an air shaft built of cinder blocks is faced with this material.

Of special interest is the use of this material where radioactive radiation occurs. As a strippable film, this material is used extensively by the Atomic Energy Commission. Used as a permanent finish, it will greatly reduce the penetration of radiation into surfaces to which it is applied, and it may be cleaned with a solution of nitric acid and live steam after exposure. A recent development of pigmenting sprayable vinyl plastic with lead powder, permits the spraying of lead linings in areas to be protected (X-ray rooms, laboratories, etc., and also for civil defense purposes).

flooring

Plastic spray applied to heavy felt or foam rubber pads forms a highly resilient and sanitary wall-to-wall carpeting. Joints between the pads (these come in rolls up to 12′ widths) and the baseboard may be sprayed over so that the entire area, regardless of size, will form a waterproof and washable surface.

This flooring has approximately the same wearing qualities as linoleum and it is excellent for stores, hospital rooms, nurseries, halls, corridors, stairs, bathrooms, kitchens, etc.

fabrics

Vinyl plastics of the strippable types, sprayed on engraved, embossed, or textured surfaces, form very attractive three-dimensional sheetings when stripped off. Various structural-glass and embossed-metal designs are readily available for this purpose.

furniture

One of the most exciting applications of plastic spray is for upholstered furniture. Sprayed directly on foam rubber, it will mold its contours and form a seamless, washable, leatherlike cover, expressing the intended design shape in its purest form. Plastic spray is also an excellent finish for wood, metal, or fiber furniture as imperfections of surface or joint will not show in the finished piece. Color and washability suggest its use for children's furniture, store fixtures, etc.

sculptures

The quality of webbing of plastic spray which permits the spanning of open spaces up to 24″ has very interesting possibilities for sculptural applications, where the tension of materials defines pure geometric forms.

miscellaneous applications

Weatherfast outdoor movie screens can be obtained by spraying aluminum- and white-pigmented vinyl on stucco or concrete surfaces. The same material may be applied to interior walls which then become decorative washable surfaces, also fulfilling the function of projection screens.

Swimming pools of any type of construction may be lined with sprayed-on vinyl-plastic sheeting.

One manufacturer of insulating materials is considering a plan to enclose glass-fiber insulation with sprayed-on vinyl plastic in order to provide a vapor seal and to facilitate the handling of the material.

application

Despite similarities in the type of equipment used, the spraying of vinyl plastic requires a completely different technique than the spraying of paint, and the technique of plastic spraying may be considered as a new craft. In view of this fact, and because of the important function which plastic spray is to fulfill in new construction, this work should be performed only by highly trained craftsmen* available through contractors specializing in architectural applications of this material, such as 20th Century Builders of Tampa, Florida, or Progressive Industries, Inc., of New York. As to specifications, it is recommended that this work be specified in a separate section under the heading: Sprayed-on Vinyl-Plastic Sheetings.

The spraying is a very clean operation because the liquid plastic, even when atomized, does not form a mist. Therefore, operators do not have to wear face masks and only a few inches immediately adjacent to the sprayed area need to be covered or masked. The odor of the solvent, somewhat unpleasant during the spraying operation, dissipates completely within a few hours. The cured material has no odor or taste whatsoever and is absolutely non-toxic.

outlook for the future

Already, original design solutions based on this new material have come from the drafting boards of professionals. Twitchell and Rudolph's guest cottages at Sarasota, Florida, with their plastic-sprayed roofs curved under tension, are presented in the following P/A feature. Engineer Fred N. Severud, besides proposing this material for atomic blast blowout panels and partitions *(page 70, September 1951 P/A)*, is considering roofing an arena of a 330′ span by stressing wire mesh over a light-steel structure and spraying a vinyl-plastic roof directly on this mesh.

The often attempted perfect geometric form for "floating structures" on stilts can now be materialized with unbroken monolithic surfaces of even texture and controlled color on all planes of the structure.

Undoubtedly, plastic spray in the hands of designers with imagination, fully exploring the possibilities of this "new skin," will bring about great changes in the design, detailing, and construction of buildings.

** In New York City this work is generally performed by the cement finishers.*

Vinyl Plastics and Resins in Architecture

BY LEONARD CONNOR*

Plastics, in general, provide qualities of durability and versatility and are vastly more suited to modern mass production methods of manufacture than many older materials; vinyl plastics, which can be applied and kept clean with ease and are economical and colorful, have many architectural applications. To more thoroughly understand the advantages and limitations of this material, one should have at least a small understanding of its chemical properties.

what are vinyl plastics and resins?

Vinyl resins in their primary state are exceedingly fine colorless powders formed by the polymerization of organic chemical molecules containing the vinyl groupings. Polymerization is a process in which molecules are linked together in long chains—a process which can be regulated so that the number of these molecules can range from hundreds to hundreds of thousands. The various vinyl compounds that lend themselves to polymerization and co-polymerization include vinyl acetate, vinyl chloride, and vinylidene chloride. With the variations that can be made in molecular weight, together with other variations that may be obtained in the basic vinyl molecule itself, the number of possible vinyl resins, theoretically possible, is infinite.

The vinyl chloride type resins, which include the vinyl chloride-acetate copolymers, account for the largest portion of these materials. Not only are they free from color, odor, and toxicity, but also they have the advantage that they can be made to any degree of flexibility by the addition of plasticizers. These characteristics make them suitable for the formulation of film and sheeting, tile, surface coatings, molded articles, and wire and cable insulation.

In preparing the flexible plastics the basic vinyl resin is mixed with small amounts of stabilizers (to minimize deterioration under exposure to heat, oxygen, and light), lubricants, and colorants, and from 25 to 45 percent by weight of plasticizer. Plasticizers, which are usually high boiling esters, convert the hard plastic into soft, flexible materials. This mixture is converted into usable forms by mixing and fusing; it can then be processed into film and sheeting of various thicknesses by means of a calendering operation. It can also be extruded as rods or tubes, or to coat wire, and it can be molded into almost any shape.

wall and window covering

Flexible film (the Society of Plastics Industry defines film as any continuous material not over 10 mils in thickness) and sheeting made from vinyl plastics can be manufactured in any thickness, although they are commercially available only in thicknesses of .003, .004, .006, .008, .010, .012, .020, .030, and .040, in continuous rolls of varying widths. The color range is unlimited and many textures are possible. Both film and sheeting are flexible, resilient, and highly resistant to tearing, abrasion, scuffing, flexing, and may be compounded so that they are resistant to fire. Because of its exceptional durability vinyl sheeting serves effectively as a wall covering material in hospital and hotel corridors, schools, restaurants, buildings and apartment lobbies, elevator cabs, railroad terminal public spaces, and department store walls. Recommended wall surface backgrounds for the application of this plastic include plaster, plywood, and sheet rock.

A relatively new vinyl material has been made by coating reinforced cellulose fibers to produce a sheeting that is flexible, crackproof, and stainproof. Used as a wall covering it can be cleaned with soap and water; for installation purposes it can be cut, stitched, or pasted with ease. Some of the uses for flexible vinyl film which may be described as adjuncts

Right—woven vinyl plastic fabric used for organ screen in church balcony. Fabric which can be cleaned without removal was applied to rough framing before the screen installation was erected in place. It is claimed that this type of screening material helps to maintain high quality of tone transmission. Architects, Saarinen, Saarinen and Associates. *Photo: courtesy of Lumite Division, Chicopee Manufacturing Corporation.*

Far right—sheeting of vinyl plastic was specified for walls of this bathroom at Levittown, Long Island. *Photo by Ben Schnall.*

Technical Editor, Bakelite Division, Union Carbide and Carbon Company.

to architectural structures, include shower curtains, window shades, and draperies. Window shades made from vinyl plastics look and feel much like conventional cloth type shades, but have many advantages over them in that the vinyl shades will not crack, fray, water spot, or wear out.

floor covering

A number of methods have been devised to convert vinyl resins into floor covering materials, each striving to retain all of the advantages that vinyl resins can contribute. The actual processes are quite different. The resulting products may be grouped into four major types of floor coverings: resilient tile; hard or rigid tile; continuous sheeting of vinyl plastic laminated to a backing material; and basic resin used as a surface coating on paper.

Resilient tile is made from filled vinyl resin compounds having, in general, a filler-resin-plasticizer ratio of approximately 40-40-20—the most common type of fillers are calcium carbonate and asbestos. Annealing of the tile is done in a pressing operation which gives the topside a smooth surface for appearance and a rough surface to the underside for better adhesion. Although the tiles are available in squares of varying sizes, the thickness is usually about ⅛". They come in solid colors and in blended marbleized designs.

The rigid tile is made from a lower molecule weight resin and a larger amount of filler is used in compounding. It can be made in a wide range of sizes and has all the important characteristics of the vinyl flooring. Indentation is less and it can take a greater amount of abuse; however, it is somewhat noisier when walked on.

Continuous vinyl flooring consists of a highly filled vinyl resin compound that is first calendered into a sheet and then laminated to an asphalt-impregnated felt backing; the resulting product is trimmed to 72" width and rolled. This tough-wearing material is easy to maintain since it is nonporous. Although wax is sometimes used to provide additional gloss, it is not necessary as a protective coating.

Another type of vinyl flooring which stands to compete, not with hard surface floorings such as those previously mentioned but with fabric, is commonly called "soft" flooring. It is made in an entirely different manner: a low cost fabric is calendered-coated with a vinyl resin which may or may not contain filler; the sheeting is deeply embossed to simulate a twist-type fabric rug, and then laminated to a thin layer of sponge rubber. This product is light in weight, flame-resistant, has excellent wearing properties, and is extremely comfortable underfoot.

Among the newest of the vinyl floorings is one made by precision printing a waterproof paper, applying a coating based on vinyl resins, and laminating the coated paper to backing material. There are countless possibilities of design, color, and styling in this type of flooring; and color is stabilized as vinyl resins will not turn yellow on aging.

surface coatings

The vinyl resins are playing an ever-increasing role in the formulation of highly successful protective and decorative coatings. Certain of these resins were developed specifically for widespread compatability with other vehicles such as alkyds, ureas, and several oleoresinous varnishes. Others have been developed for service in primers and undercoats. Being colorless themselves, the resins allow the formulator a full range of color possibilities.

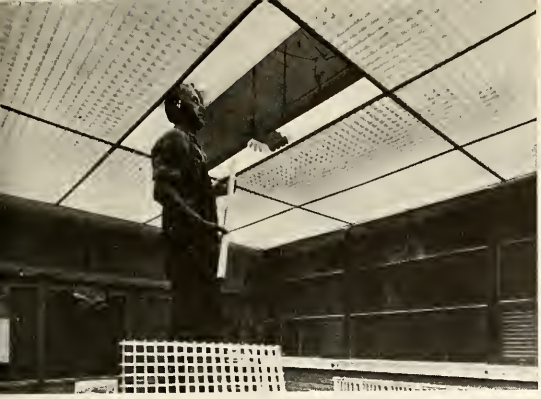
Among the newer developments is a vinyl resin coating for application

Easy-to-clean, woven vinyl plastic fabrics are frequently specified by furniture designers. Above—a twill weave fabric has been stretched between the aluminum tubing of this rocker-type chair designed by Bartolucci-Waldheim. *Photo: courtesy of Lumite Division, of Chicopee Manufacturing Corporation.*

Above, right—the back and seat of this all-around work chair which swivels, turns, and rolls is of foam rubber upholstered in woven plastic. *Photo: courtesy of Knoll Associates, Inc.*

Below, left—several types of flooring are made from vinyl resin compounds. Resilient tiles, similar to those pictured, are available in varying sizes; however, the thickness is usually about 1/8". *Photo: courtesy of Bakelite Division, Union Carbide and Carbon Corporation.*

Below—vinyl plastic flooring is highly satisfactory for beauty salons. In this photo, 18" square tiles have been laid in combination with feature strips. *Photo: courtesy of Delaware Floor Products, Incorporated.*



Above—luminous ceiling in reading room of Fitchburg Youth Library combines cold cathode lamps with a corrugated vinyl ceiling surface. Architects, Carl Koch and Associates. *Photo: Ezra Stoller © Pictor.*

Other uses of this material are: left, above—rigid vinyl plastics for louverall ceiling in an industrial office; left, below—vinyl resin base coatings sprayed on exterior cement block walls provide a tough, nonporous film; below—primary insulation and jacketing for single, double, and multiple electrical conductors. *All photos: courtesy of Bakelite Division, Union Carbide and Carbon Corporation.*

on brick, stucco, concrete, concrete block, and cinder block. This coating provides a tough, nonporous film that resists weathering, industrial fumes, acids, alkalies, salt spray, oils, greases, and cleaning solutions. The coating is being used on homes, apartment and office buildings, service stations, stores, and industrial buildings such as factories, smelting plants, and other structures where corrosive fumes are prevalent. Coatings for swimming pools in both color and in white have shown high resistance to fresh and salt water and to the disinfectants that may be present. In damp basements, the use of these coatings provides dry, clean, and easily maintained walls for years of useful service.

ceiling louvers

Rigid materials made from vinyl plastics are well adapted to the demands of architects and engineers who require a permanent, colorful, easily fabricated thermoplastic. They differ from the flexible plastics chiefly in that no plasticizer is used. The basic resin, stabilizers, lubricants, and colorants are mixed together and heat-processed into a number of forms, including sheet, extruded shapes, and molded articles.

One application of architectural importance is the use of rigid vinyl plastic for louverall lighting. In contrast with opaque materials commonly used, the plastic not only rejects 18 percent of the light striking the surface, but also allows 71 percent transmission.

In an application of this type, vinyl plastic proves its dimensional and color stability and nonwarping and noninflammable qualities. The toughness of the plastic minimizes the possibility of damage during shipping, handling, installation, or cleaning.

wire and cable insulation

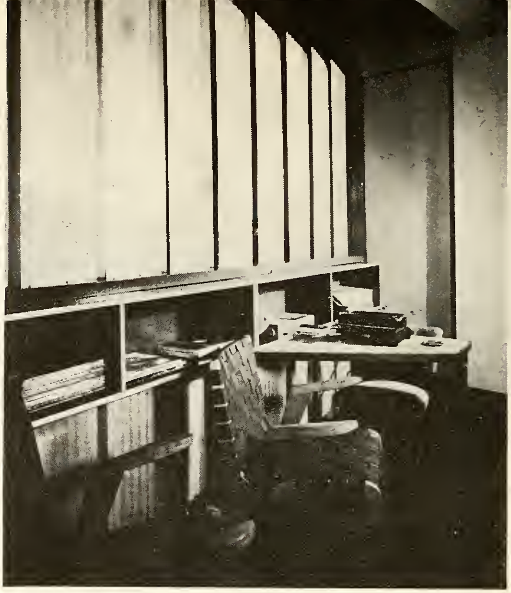
The nonconductive characteristics of vinyl resins make them particularly suitable for use in the manufacture of electrical insulating materials. In addition, these resins have physical and chemical properties that provide full protection to both wire and cable when used either as the primary insulation or as jacketing, in the various conditions that may be found in service.

Vinyl plastic insulating compounds have brought a number of advantages to the wire and cable industries: The high dielectric and physical strength of these materials, which obviates the need for fibrous rovings or braids, permits the construction of thin-wall insulation and, hence, the insertion of a greater number of circuits in existing conduits. Since the basic resins are colorless, the insulating compounds may be made either in transparent or opaque colors. These color possibilities are of special interest in complex circuits where positive tracing is necessary. Special inks have been developed for striping the insulation, making the coding possibilities limitless.

These compounds may be formulated to produce noninflammable insulation. They are resistant to weak acids and alkalies, to oils and greases, to weathering, to abrasion, and to the rough handling they might receive when used on household appliances. They have extremely low moisture absorption. They can be formulated to have exceptionally high flexibility at low temperatures.

Underwriters' Laboratories have listed these various compounds as suitable for a broad range of applications, such as building wire in both dry and wet locations, 80C (145F) switchboard and appliance wire, and even when exposed to oil as high as 60C (110F). Many of the compounds have been listed as suitable for combinations of these applications, including their versatility.

Appearing with increasing frequency since the war, acrylic plastic has a wide range of possibilities as a builder's material. As in other materials, proper installation reflects the nature, characteristics, and appearance of the plastic, and its use as a mere substitute may prove impractical or uneconomical or both. The coauthors have discussed its application possibilities, properties and limitations, optical and safety considerations, machining techniques, and installation methods.



Acrylic Plastics in Architecture

BY FREDERICK W. TETZLAFF AND ROBERT R. RORKE*

The growing popularity of acrylic plastics in architecture, dating from the close of the war, indicates that a greater familiarity with the applications, properties, and limitations of this material may be useful to the design professions.

Applications range from corrosion-resistant glazing in chemical plants, to decorative screens and partitions in specialty shops; from skylights in small homes, to paneled ceilings and walls in hotels; and from shower enclosures to store fronts. In these and many other ways, this plastic is proving its worth as a builder's material.

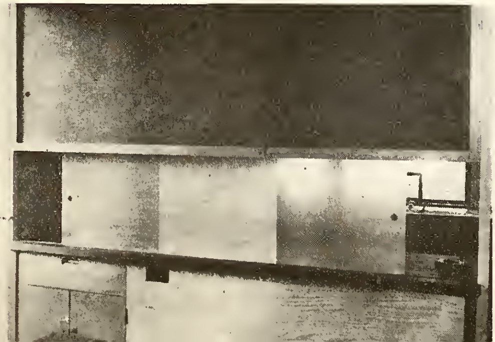
Acrylic plastic, in the form of cast sheet, is manufactured by the Rohm & Haas Co., and marketed as Plexiglas. This new and remarkable material is transparent, translucent, opaque, and has a full range of colors. It offers the architect a combination of properties not found in any other material: light weight (48 percent that of glass), high resistance to breakage, excellent weatherability, virtually perfect transparency or ideal diffusion, the ability to pipe light, and the ease with which it is formed or machined.

Its most successful use, however, presupposes proper application, installation, and maintenance, just as in other standard materials, and should reflect the nature, characteristics, and appearance of the plastic. Normally, its use as a mere substitute for other materials can prove either impracticable or uneconomical, due to the failure of taking fullest advantage of the acrylic's inherent properties.

One of the commonest and most effective uses of cast acrylic sheet is in partitions, where the architect requires strength and light-transmitting properties.

Translucent panels often are used in corrugated form to admit light while maintaining privacy. Typical examples: as entrance screens to executive offices; at switchboards and reception desks; and at credit and employment interviewing booths. In the home, corrugated sheet may form a decorative panel to separate dining room and kitchen, or to shield kitchenette from living quarters while still giving a feeling of spaciousness to small rooms.

Inside stairways enclosed by this plastic instead of the usual balustrade, may provide a light and cheerful entrance hall and reduce drafts.



Upper left: Partition is formed by separate white translucent corrugated sheets placed in louver pattern. Left: Clear panels, sanded for translucency, are lightweight, chip-proof, and shatter-resistant. Panels slide easily and safely.

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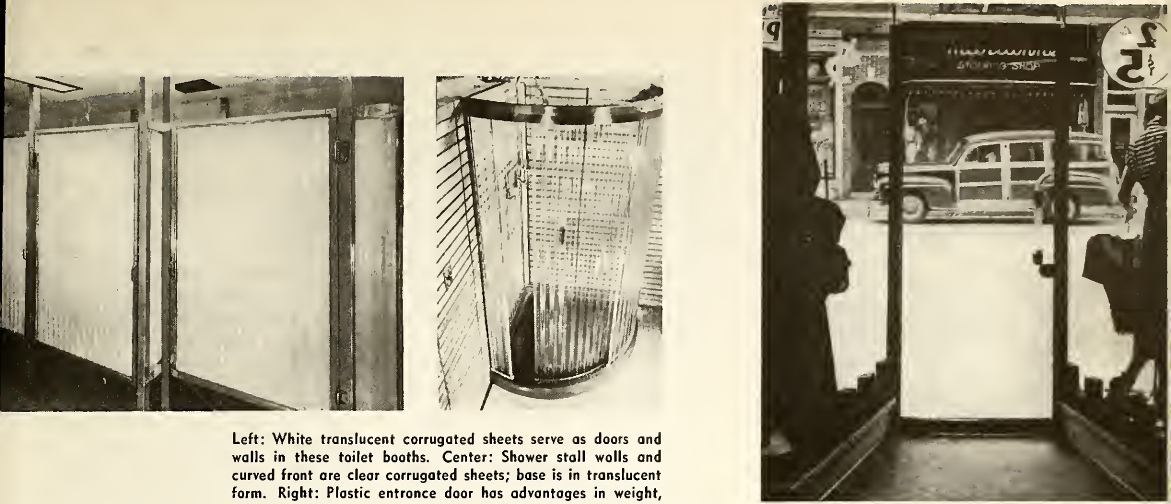
* *Rohm & Haas Co., Philadelphia, Pa.*



Left: White translucent corrugated sheets serve as doors and walls in these toilet booths. Center: Shower stall walls and curved front are clear corrugated sheets; base is in translucent form. Right: Plastic entrance door has advantages in weight, safety, and cost. *Photo at right: da Silva*

Corrugated, Patterned Material

The corrugated material is flexible enough to be curved to a comparatively short radius, and yet retain great transverse rigidity. Strip-heated parallel to the corrugations, it can be bent to any curve or angle; also, it can be strip-heated and bent transversely without loss of the corrugated form. Although acrylic sheet can be corrugated to any desired dimensions, standard corrugations are in 1″ frequency by ⅜″ amplitude, and 2½″ by 1″.

Patterns can be applied during manufacture to the surfaces of both corrugated and flat sheet. In the former case, patterns are at right angles to the corrugations. Standard patterns include wide and narrow flutings, ribbed, pebbled, dotted, frosted, and cross-hatched designs. Normally, they appear on one surface only, but may be applied to both on order.

Flat sheet is finding increasing use in horizontal and vertical surfaces in schools, hotels, and other public buildings where resistance to breakage, resilience, and ease of cleaning are important.

Store Fronts

One of the recent developments in the architectural field has been the use of acrylics for store fronts. Designers of filling stations, too, are specifying this plastic for distinctive exteriors. Sometimes curved or corrugated, they have color permanence, can be cleaned easily, and require no maintenance.

Skylights

Corrugated acrylic plastic may be combined with corrugated metal roofing to provide weather-tight skylights. It does not require special framing or built-up openings. Also, it can replace broken glass panes in existing skylights.

Because of its strength and light weight, large sheets can be installed without supporting ribs. Alternately, the material may be formed into a dome, much as aircraft enclosures are made. Small formed skylights of this type have been installed in the homes of several housing developments, including the Six Moon Hill Group in Lexington, Massachusetts, and a housing project in New Haven, Connecticut.

Lighting

One of the newer and more important adaptations of architectural lighting converts large ceiling areas, in effect, into a lighting fixture. This may be accomplished with flat and corrugated sheets of translucent material, or with formed panels. In either case, this material exhibits ideal diffusing properties for producing the wide-area, low-intensity lighting desired. The white translucent material undergoes no appreciable color change under prolonged exposure to fluorescent light.

An interesting property of this plastic is its light-piping ability, familiar for its common use in signs. Virtually all the light admitted at one edge will escape only at other edges, or wherever the surface polish is broken as by shading, sand-blasting, carving, or engraving.

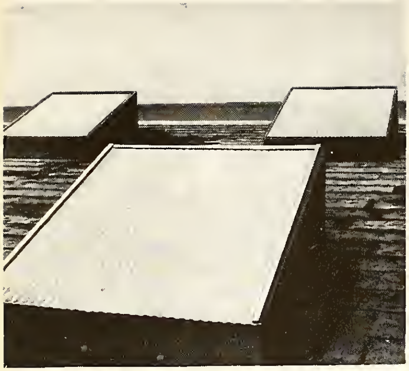
Piping light around very sharp curves or angles should not be attempted; the limiting angle is 48° and the limiting inside radius of curvature is twice the thickness of the section. To carry light around sharper curvatures, layers of the plastic should be assembled in graduated thicknesses, each sheet curved to a radius three times its thickness.

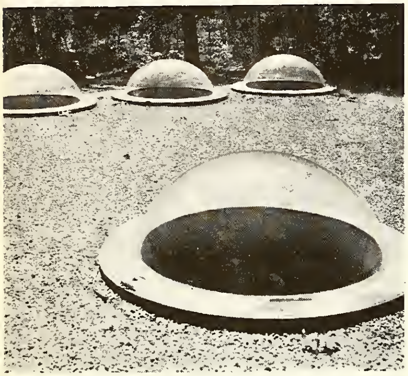
A newer form of the material is fluorescent; presently available in red, green, or yellow, it exhibits this edge-lighting property in the area exposed to room lighting. Fluorescence of this material is not permanent under exposure to direct sunlight.

Optical Considerations

Even with the most advanced manufacturing methods, it is impossible to cast a transparent plastic sheet with two perfectly plane and parallel surfaces. Thus, where even slight optical deviations could be considered a defect, the line of sight should be kept as nearly perpendicular to the surface of the acrylic as possible.

At perpendicularity, 92 percent of the light is transmitted, and 8 percent reflected, but as this line moves away from the perpendicular, a higher percentage of light is reflected. At an angle of incidence of 85°, for example, the light transmission drops virtually to zero, as in any transparent material. Accordingly, the architect should keep the angle of incidence below 50°. Design-wise,





Top: Large sheets, without supporting ribs, are used in these skylights. Above: Dome-shaped transparent skylights, located on roof, admit light to living room, dining room, study, and kitchen of this home. Lower left: Plastic sheets, corrugated to match metal walls, provide easy, weather-proof installation. Right: Resilient panes reduce breakage in school windows exposed to play areas.

this means that curved panels should be formed with cylindrical or spherical shapes; for maximum optical clarity, such panels in store or other display use should be designed to place the observer at the center of curvature. To avoid excessive reflection losses, and as a practical fabrication consideration, the radius or curved sections should be kept at a minimum of 6 inches.

It is possible to produce a cemented or heat-welded joint approximating the material itself in strength and transparency. Generally, however, it is better to take advantage of the possibility of forming the material to avoid cemented corners. Acrylic sheet can be formed to almost any curvature while it is hot (220F. to 300F.). Between these two temperatures, it behaves like a sheet of pure gum rubber; it can be "stretch-formed" by pulling evenly on opposite edges, or shaped over a simple plaster or plywood form. In the hands of fabricators, it can be formed by vacuum, plug-and-ring, or vacuum snapback methods. Cooled to room temperature, it will retain curvature; reheated, it will resume its flat condition.

Safety Considerations

Acrylics will easily withstand a blow which would shatter glass of equal thickness; but if broken, it breaks into relatively large, dull-edged pieces. This characteristic has led to its use as glazing in children's playrooms, and in institutional wards where mental patients may become violent.

This material is particularly well adapted also to industrial glazing, especially on buildings with Robertson metal sidings—corrugated sheet iron surface-bonded with corrosion-resistant material. Many industrial operations create severe corrosion problems; paint disintegrates and sash metal corrodes quickly. In such cases, the plastic may be corrugated to match the Robertson metal and installed to overlap the window openings. Such a "window" may be expected to be as permanent as the building itself, because it is unaffected by weather and is resistant to virtually all corrosive forms.

The importance of shatter-resistance in such glazing is emphasized in many industrial installations—as in a foundry where cutting machines throw glomerations of sand, iron slugs, and chips, resulting in a continual breakage of glass panes. Use of translucent sheet for glazing has shown another advantage—that of providing soft, even lighting in place of the contrasting glare and shadow from undiffused sunlight.

In glazing, the sheet material passes most of the therapeutic band, including the erythemic or "sun-tanning" frequencies, and the so-called "vital" range. If desired, dyes may be added to obtain an ultraviolet filter, though this treatment, of course, reduces transmission of visible light. Also, a special UV-absorbing sheet has been developed which will not transmit wave lengths of light that produce sunburn.

Machining Techniques

Workability, similar to that of brass and copper, includes sawing, drilling, machining, threading, routing, and swaging. Cutting edges of tools should have no rake, and should have a scraping rather than a cutting action. Tools and work should be held firmly to prevent chatter. A water or oil coolant may be used but this is not essential. Feed should be constant throughout the cut; if the work stops, it will be "burned."

Ordinary hand or power saws may be used, but where much fabrication is to be done, it is advisable to reserve special saws—circular, band, or scroll.

Two major precautions should be borne in mind when specifying acrylics or directing their installations. First, excessive localized stresses are likely to develop a surface pattern of tiny fissures known as "crazing," just as woods split and metals crack under similar abuse. Second, the plastic's coefficient of expansion is three to five times greater than that of metals. Hence, it must be allowed to contract or expand in relation to the contraction or expansion of any metal frame or channel into which it is fitted.

Republication of this article, written when the use of acrylic plastic by architects was still in its comparative infancy, provides an opportunity to outline the major applications that have evolved since.

Formed-dome skylights are now used extensively for daylighting schools, homes, and industrial plants. They are available as prefabricated units, complete with frames and flashing, from a number of specialty building product manufacturers.

In *architectural glazing* good use is is being made of large neutral-color plastic sheets, formed to a deep v-rib corrugation. Such panels have exceptional rigidity, give textural interest to extensive daylight-admission spans, and tend to reduce solar glare and heat. In addition, flat acrylic panels in gray and green colors are being installed as vision strips below extensive areas of glass block.

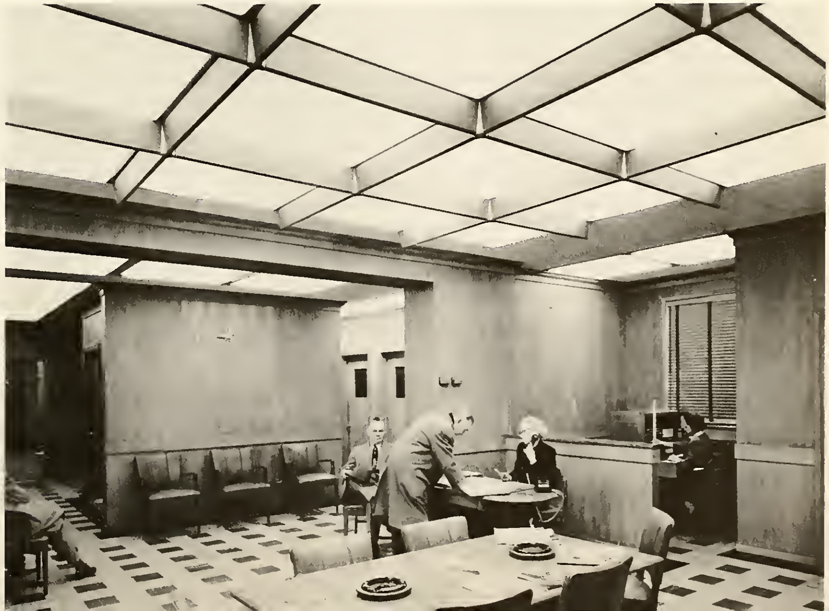
A recent interesting development in glazing for control of sun and sky glare is the use of acrylic panels formed into a series of deep louvers, with reflective paint applied to the ends and tops of each louver.

Luminous ceilings and large-area luminous fixtures with translucent acrylic diffusers mounted below fluorescent tubes are widely used today. The excellent diffusion obtainable with acrylic has also led to its incorporation in standard fluorescent fixtures.

Shower enclosures, consisting of rigid corrugated sheets mounted on the rims of recessed bathtubs, have evolved from the curved, custom enclosure described above. A number of manufacturers supply such shower enclosure units.

The use of acrylic plastic for *signs* has kept pace with the increased consideration given by architects to the means of identifying a building. Acrylic letters and sign faces, backlighted for over-all luminosity at night, have proved appealing from an esthetic as well as a functional standpoint. This is particularly true in the case of institutional buildings and office buildings, but architects have also used the material for signs on a large number of commercial structures such as stores and restaurants. In many new shopping centers the architectural specifications have included the use of acrylic signs by all commercial tenants.

Large panels of white translucent acrylic plastic, mounted below fluorescent tubes, provide a high level of diffused light. They are often combined with acoustical baffles.



INTERIOR MATERIALS

One of the most useful interior partitions for classrooms is the new floor-to-ceiling chalkboard panel developed by the United States Plywood Corporation. These unusual panels combine several different materials, perform several functions at once, and in a pilot installation at the Newfield Elementary School, Stamford, Connecticut, they also helped to reduce construction time and costs. (Sherwood, Mills & Smith were the architects.) Besides providing generous size writing surfaces, these metal panels attract magnetic devices used in conjunction with training aids and help provide good hearing conditions by reducing sound transmission between classrooms. These units are actually made up of three separate panels. Both exterior laminations are composed of 18-gage porcelain-enamel steel (special frit for chalk writing), ¼ in. fir plywood, and 24-gage zinc-coated steel. Three and one-half in. of cane fiberboard make up the interior core. As sound transmission is related to the mass of the partition, a weight of 10 psf, providing a decibel rating of 39, was specified for the 2′ x 10′ panels. On both flanks of the installed panels (six were used for the chalkboard area at the Newfield School) zinc-coated steel units (for better painting surfaces) were erected. To provide the necessary 10 psf, two 16-gage steel sheets were laminated to 4 in. cane fiberboard. Both types of panels are held in place by three devices: wood splines between units, structural-steel angles at the ceiling, and continuous track at floor level (half-spline width). Although no precise figures can be cited for erection costs, it was observed in this first installation that two mechanics and a helper were able to erect a 10′ x 30′ area in 24 man hours or less. For future chalkboards, this manufacturer will offer a lamination of two 18-gage porcelain-enamel steel sheets separated by a 2 in. gypsum core (also weighing 10 psf); side panels will similarly consist of 24-gage zinc-coated steel units laminated to a 2 in. gypsum core. The former panels will cost about $3.50 to $3.75 per sq ft and the latter approximately $1.25 to $1.40 per sq ft.

Interior Wall Materials for Residences

BY GROFF CONKLIN

As far as the architect is concerned, the selection of materials for the inner walls of houses is and always has been a complex problem of compromising with the client's desires, comparative costs and availabilities, and the architect's own taste and imagination. There certainly is nothing wrong with this; indeed, it is probable that these will continue to be the chief desiderata in the selection of wall materials, no matter what information is developed in this review.

The fact is, however, that there are several important *performance* factors against which a wall material should be measured. Everything else being equal, it would seem only logical that a material which best combines the various performance qualities deemed desirable in the inner walls of a residence should be the material of choice. It is the purpose of this review to provide architects with a brief analysis of these qualities, to establish insofar as possible some sensible, tested standards below which a material may be said to be unsuitable for the purpose to which the test applies, and to evaluate the various available materials and combinations of materials in terms of these standards.

performance aspects of wall materials

The most important elements to be considered in evaluating the performance of any particular wall material, or of that material as an integral part of a wall cross-section, are:

Strength: compressive, transverse, concentrated, impact, and racking loads.

Fire safety: in minutes, or hours, of ultimate fire resistance.

Insulating efficiency: in conductivity "K" or conductance "C" for a material or coefficient of transmission "U" for a wall cross-section.

Acoustical insulation: in rate of decibel reduction of a standard sound passing through a material or wall.

Rot resistance, insect, and rodent proofness: the standards here are essentially pragmatic; though materials "proofed" against these enemies of the house can be tested for efficiency, no fixed standard has successfully been determined as a measuring rod.

There is no intention, in this review, of analyzing the performance of interior wall materials in relation to various climatic or regional conditions. To attempt such a study would extend the length of this report to encyclopedic dimensions, without being in any way definitive. Materials will be examined in terms of scientific standards, from which by logical extrapolation plus local experience, the architect can establish the requirements necessitated by his particular geographic location.

standards for measuring wall materials' performance qualities

The standards described below are neither counsels of perfection, nor are they on the other hand derived from manufacturers' catalogs. They are practical judgments by highly skilled experts of what is possible and desirable in the average residence or apartment house located outside of the fire limits and building code areas of a city or town. They are not, of course, to be taken as suggested substitutes for/or modifications of the requirements of any building or fire code. In heavily built-up areas, these requirements must always hold precedence. On the whole, the suggested standards can be met within the limits of a very modest construction budget, as will be seen when the individual materials themselves are discussed.

The suggested standards, which are the outcome of many years of study by government and private laboratories, present the most reasonable compromises between ideal or perfect conditions and the costs of materials and construction techniques necessary to achieve those conditions. Most of them have been derived from tests performed by the National Bureau of Standards of the United States Department of Commerce, which for over twelve years has been engaged in a systematic examination of the materials used in residential construction. The results of these studies have been published in the Bureau's well-known series of technical reports, "Building Materials and Structures" (BMS), in which 120 titles have already appeared. In some instances the standards suggested have not actually been stated in so many words by the Bureau, but are deduced or synthesized from the data the Bureau has presented.

Other sources of information include the annual *Guide* of the American Society of Heating and Ventilating Engineers, and the Housing and Home Finance Agency's 1947 *Manual on Wood Construction for Prefabricated Houses*—these volumes providing most of the data on thermal conductivity used in this review.

strength

In general, the strength of an interior wall material from the point of view of load is a factor of secondary importance in the strength of the total wall construction. The framing provides at least half, and often more, of the total strength; exterior wall materials add still more; and factors other than the materials themselves, such as workmanship and construction methods, often decisively affect the figure.

In a sense, it is fortunate that this is so, for the Bureau of Standards has not as yet completed its series of tests on the strength of all wall materials. It is impossible, consequently, to present a complete check-list of comparative strength standards for the various wallboards, lath-and-plaster combinations, and the like. The data presented in Table 1 are merely test results on a few specific materials or material combinations, and do not in any way pretend to offer a final standard. Rather, they merely indicate how much punishment certain types of wall construction will take, according to the tests-to-destruction performed by the Bureau.

For full data on what the tests actually are, the reader is referred to the pertinent BMS reports, particularly BMS 25, "Structural Properties of Conventional Wood-Frame Construction for Walls, Partitions, Roofs, and Floors." Wall QA, which is composed of wood lath and plaster on the inside, wood studs, yellow pine

Table 1: Strength Data on Various Wall Constructions(1, 2)
(See text for description of standard wall)

Wall material	Maximum compressive load (lb/ft)	Maximum transverse load (inside face) (lb/sq ft)	Maximum concentrated load (inside face) (lb)	Maximum impact load (inside face (3) ht of drop in feet)	Maximum racking load (lb/ft)	Source BMS Report No.
Stud frame only	3680	182	—	—	—	25 (Panel QAF)
Wall QA (wood lath and plaster)	8380	273	306	9⅔	2090	25 (Panel QA)
Plywood (¼" wallboard, 3/16" sheath)	5620	212	683	No failure at 10 ft	1400	30 (Panel BU)
Insulite (½" wallboard, 25/32" sheath)	6700	270	150	8.7 (ft)	1540	31 (Panel BI)
Celotex (½" wallboard, 25/32" sheath)	4540	288	106	No failure at 10 ft	1390	42 (Panel BY)
Homasote (½" wallboard and sheath)	5120	412	237	No failure at 10 ft	790	48 (Panel CN)

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(1) Figures for gypsum lath and plaster and for gypsum wallboard are unfortunately not presented in the BMS series. It is assumed from other evidence that these materials are at least as strong as comparable constructions listed above.

(2) These are all of the wall sections involving the use of specific, different inner wall materials thus far published by the Bureau of Standards. Data for masonry wall constructions and many special patented types of prefabrication are also available in the BMS series, but have no application to this immediate study.

(3) Impact load in these tests consists of a sandbag 28" high and 29" wide, weighing 60 lbs. (BMS Report 2, page 11). Consequently, this is not a test for sharp impact, such as a hammer blow or a blow with a baseball or some other concentrated object. Tests for this kind of impact have never been reported by the Bureau of Standards, even though the situation is one which frequently obtains in homes, especially those with children.

sheathing, building paper, and red cedar siding, is a standard construction which, with minor variations, is used throughout the tests of wall materials, the only changes being the substitution of the various wall materials being tested for the lath and plaster, and also occasionally the sheathing.

Inasmuch as the figures given in Table 1 are maxima, they obviously cannot be used as standards. They are the figures at which actual failure in the panel occurred.

As far as the walls of residences go in general, considering not only the inner surfacing materials but also the whole structural unit and the outer materials, all locally standard wall constructions are sufficiently strong to stand up under normal usage in the area to which they are pertinent—and, indeed, to withstand the most violent weather conditions likely to be encountered in a given area. Experience over more than two centuries has resulted in adequate rule-of-thumb strength standards for the walls of buildings in various regions, and many minimum strength requirements have been written into Federal Housing Administration regulations and other official documents. For anyone who is interested in the problems connected with the strength of various parts of residences, the Bureau of Standards BMS report 109, called "Strength of Houses" (1948), offers a mine of useful technical information. It is, however, essentially uninformative on the strength aspects of inner wall materials.

fire safety

The problem of fire safety in homes, particularly in those of medium cost, is one to which much too little attention is paid. There seems to be a fairly common assumption among manufacturers, builders, home buyers, and architects—even among certain testing and standards agencies which should be concerned with the problem—that there is little or no need to provide any minimum degree of fire safety in the materials going into a residence outside the fire limits of an urban area—particularly the materials that cover the walls and ceilings inside the house.

This conclusion stems inescapably from reassuring statements by experts as responsible as insurance officials and actuaries that fires occur in homes with a frequency so small that no one particular house is likely to have a fire of any type more than once every sixty years. This truism, with its beautiful illogical assumption—actually, averages do not mean anything in this connection, and *any* one may have a fire at *any* time—is also illuminated by the fact that the National Board of Fire Underwriters, one of the groups responsible for establishing standards of fire safety for all types of construction, has nothing to offer on the problem of fire-safe materials or construction for residences beyond building or fire code limit. Yet it is in the suburban and rural areas that such a large proportion of the country's new residential construction is located and that so many devastating fires occur. Finally, the notorious laxity of many codes applying to residential construction outside of a town's fire limits is indicated by the practically universal absence from these codes of standards for fire-safe wall materials.

It is the poorest kind of logic to base a design philosophy on the notion that the eventual probable catastrophe will never occur in the structure under consideration. If a moderate amount of fire safety can be achieved at no cost, or at most at a cost of only one to two percent more than those of a completely unprotected house, it would seem to be not only stupid but irresponsible to to ignore that safety margin.

The inner wall materials of a house should be as fire-safe as the nature of the usable materials and the limitations of budget allowance. The problem is, of course, what standard of safety in wall materials and wall cross-sections should be the minimum acceptable to the alert architect concerned with protecting his client's interests. The Bureau of Standards, in its BMS Report 92, has worked out a series of fire rating classifications for structures of different materials, design, and use, which is extremely useful in this connection.

In BMS 92, structures are divided into four types, each type being defined as a certain level of excellence of fire resistance. Types I, II, and III are primarily urban buildings—factories, office buildings, institutional structures, apartment houses and hotels, and also row-house residences built within the fire limits of most

Table 2: Wood-Framed Partitions (Rated as load-bearing except as noted)

	Thickness of board or plaster in facing and ultimate fire-resistance period									
	⅜"		½"		¾"		⅞"		1"	
	hr	min	hr	min	hr	min	hr	min	hr	min
Facings of boards without plaster										
Fiberboard weighing 0.7 lb/sq ft				10						
Fiberboard weighing 1.1 lb/sq ft				15						
Flameproofed fiberboard weighing 1.6 lb/sq ft as treated				30						
T & g wood boards						20				
T & g wood boards with mineral-wool fill						35				
T & g wood boards with asbestos paper weighing 30 lb/sq ft between boards and studs						45				
Gypsum wallboard		25		40						
Gypsum wallboard with mineral-wool fill				45						
Gypsum wallboard with mineral-wool fill, rated as nonbearing			1							
Gypsum wallboard with mineral-wool batts nailed to studs			1							
Facings of plaster on wood lath										
1:2, 1:3 gypsum plaster				30						
1:2, 1:3 gypsum plaster with mineral-wool fill			1							
1:5, 1:7.5 lime plaster				30						
1:5, 1:7.5 lime plaster with mineral-wool fill				45						
Facings of plaster on board plaster bases										
1:2, 1:2 gypsum plaster on ½" fiberboard weighing 0.7 lb/sq ft				35						
1:2, 1:2 gypsum plaster on ⅞" flame-proofed fiberboard weighing 2.8 lb/sq ft as treated			1							
1:3, 1:3 gypsum plaster on 1" magnesium oxysulfate wood fiberboard				45						
Neat gypsum plaster on ⅜" plain gypsum lath			1							
1:2, 1:2 gypsum plaster on ⅜" plain gypsum lath with 1¾" by 1¾" metal lath pads nailed 8" centers vertically, 16" centers horizontally			1							
1:2, 1:2 gypsum plaster on ⅜" perforated gypsum lath, one ¾" diameter hole or larger per not more than 16 sq in. of lath surface			1							
1:2, 1:2 gypsum plaster on ⅜" gypsum lath, plain, indented, or perforated other than as above				45						
Facings of plaster on metal lath										
1:2, 1:3 gypsum plaster						45	1			
1:2, 1:3 gypsum plaster with mineral-wool fill					1	15	1	30		
1:2, 1:2 gypsum plaster					1					
1:2, 1:2 gypsum plaster with mineral-wool fill					1	30				
Neat gypsum plaster					1	30				
Neat gypsum plaster rated as nonbearing					1	30	1	45	2	
1:2, 1:3 portland cement plaster						30		45		
1:1/30:2, 1:1/30:3 portland cement and asbestos fiber plaster						45	1			
1:5, 1:7.5 lime plaster						30				
2:1:8, 2:1:10 lime and portland cement plaster						30				
2:1:8, 2:1:12 lime and Keene's cement plaster						45				

towns. They do not apply in most instances to the free-standing residence in suburban or rural surroundings.

Type IV refers to buildings of wood construction, either all-wood throughout, or masonry veneered or provided with some other incombustible exterior finish. Most, if not all, residences obviously fall under Type IV. In the Bureau's method of subclassification, Type IV is divided into two parts. Type IV-A refers to wood construction with a ¾-hour fire resistance rating or better; Type IV-B is wood construction with less than a ¾-hour rating. No home should be built of materials and with construction methods which would take the structure out of the Type IV-A class —that is, which would provide less than ¾-hours fire resistance, as established by Bureau of Standards tests. Particularly since this rating can be achieved with low-cost and readily accessible materials, to recommend less would be to approve an entirely unnecessary risk.

The Bureau of Standards classifications have been arrived at in entirely modern and scientific manner. BMS 92, on page 5, says: "The fire-resistance classifications of building types heretofore generally have been defined in terms of established constructions and materials. The classification contained (in this report) is based on *performance* in fires and fire tests, graduated within each type." (Author's emphasis.) By establishing performance ratings, the Bureau has made it possible for architects to use *any* materials which actually perform in accordance with the standards set — provided, of course, that the local building authorities permit their use.

Table 2, containing ultimate fire-resistance period ratings for wood-framed walls and partitions, is taken from BMS 92, page 34. It establishes fire-safety periods for a wide variety of wall constructions commonly found in wood-frame buildings.

insulating efficiency

The only reason for discussing insulating efficiency in connection with wall materials used inside the house is the fact that so much emphasis in the past ten or more years has been placed on the values of the so-called insulating wallboards. When other types of wall materials are used, insulation is provided by placing noncombustible wools or batts between the studs of a wall and the joists of a ceiling exposed to an unheated attic. The various qualities of the insulating wallboards themselves will be discussed, along with other specific wall materials and their related properties in subsequent paragraphs of this article.

Meanwhile, to establish a standard for insulating efficiency, both in walls and in ceilings or attics, the lowest design temperature of the region in which the house is to be built must be known, and must be applied to the formula for figuring the "U" factor or coefficient of heat transmission of a given construction. According to the Housing and Home Finance Agency's *Manual on Wood Construction for Prefabricated Houses*, page 118, "It has been generally accepted that a proper air temperature for residences is 70°F but no standard has been so far established for the surface temperature of enclosing floors, walls, and ceilings. It is generally agreed, however, that the closer these surface temperatures are to 70°F, the greater is the degree of comfort, and that surface temperatures more than 10°F lower than the air temperature is a prominent cause of discomfort. A standard for surface temperature of not less than 64°F is suggested as one that is reasonable from the standpoint of comfort, and practical and economical from the standpoint of availability of insulating materials."

To arrive at an accurate analysis of what is required to deliver an inner wall surface temperature of 64°F in various minimum design degree zones in this country is far beyond the scope of this review. The manual quoted above gives, on page 127, a series of simple equations for arriving at the necessary amount of insulation required, given the minimum design degree for the region in which the house is to be built. These equations will prove essential to any architect planning to work out his own insulation data.

With the exception of the insulating wallboards, no standard inner wall materials have insulating values of a sort which affect the insulation requirements to any great degree; if they did, insulation itself would have proved unnecessary in most homes. The actual insulating qualities of common wall materials and wall constructions are presented in abbreviated form in Table 3, which is a cutdown version of a much longer table appearing on pages 125-126 of the manual quoted above. It omits all masonry and roofing materials, and several other materials and constructions not ordinarily found in residences.

Table 3: Conductivity or Conductance Values for Materials or Air Spaces Expressed in British Thermal Units Per Hour Per Square Foot Per 1°F. Temperature Difference on Opposite Sides of the Material(1, 2) (The lower the conductivity, the better the insulating value)

Material	Description	Conductivity or Conductance
Air bounded by ordinary materials	¾" or more in width	Through walls 1.10
Space divided by double aluminum foil	1½" or more in width	Through walls 0.23
Batts and blankets (also loose fill)	1" thick, mineral or vegetable fiber, or animal hair	0.27
Cork board	1", no added binder	0.30
Gypsum board	⅜", plain or decorated	3.70
Gypsum lath & plaster	Plaster assumed ½"	2.40
Insulating wallboard	½" plain or decorated	0.66
Insulating lath & plaster	½" lath, ½" plaster	0.60
Metal lath & plaster	Plaster assumed ¾"	4.40
Plywood (C depends entirely on woods used. No one figure can be given, since several types differ.)		——
Wood lath & plaster	Standard thicknesses	2.50
Insulating fiberboard sheathing	25/32" thick	0.42
Wood (probably pine)	25/32" thick	1.02
Wood plus building paper	25/32" thick plus the paper	0.86
Vermiculite	1" thick, expanded	0.48

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(1) A much wider variety of insulating materials, most of them actually reported by trademark, is listed in the Forest Product Laboratory's *Wood Handbook* (1940), on pages 300-302. Unfortunately, a number of the products there listed are no longer available; but for those which are, accurate C factors are given: the only source in government where products are actually evaluated by brand name.

(2) Conductivity "K" and Conductance "C" are to all intents and purposes the same factor when a material is being considered as part of a wall cross-section. "K" refers to the time rate of heat flow through a homogeneous material under study conditions, a homogeneous material being one in which the value of "K" is not affected by variation in thickness or size of sample within normal ranges used in construction. "C" refers to specific materials as used, either homogeneous or heterogeneous, and particularly covers materials of specific thicknesses. "K" is the rate per inch of a homogeneous material; "C" is the rate for a material of a specific thickness. "C" is also used to refer to the conductance of air spaces.

acoustical insulation

The ability of a wall material to deaden sounds passing from one room to another or from outdoors into the building is a further important element in its over-all value. The Bureau of Standards has run a series of tests of wall and floor panels which accurately measure the acoustical efficiency of most of the commonly used materials and constructions, and has reported the data in BMS 17, plus two supplements.

Sound reduction, like sound itself, is measured in decibels. In order to arrive at a standard for effective *sound transmission loss* in walls, or the amount to which a test noise is reduced in intensity when passing through the walls, the author had to look elsewhere than in BMS 17, since it seems to be Standards policy never to recommend standards in its technical reports.

In *Building Insulation,* second edition, published by the American Technical Society, on page 281, the author Paul D. Close has stated, ". . . it is somewhat hazardous to attempt to establish hard and fast rules relative to the proper sound-reduction factors required under various conditions. With an average reduction of 25 decibels, normal speech can be understood quite easily and distinctly through the wall or partition. With a reduction of 30 decibels, loud speech can be understood fairly well on the opposite side of a partition if conditions are quiet. With a reduction of 35 decibels, loud speech is audible but not intelligible on the opposite side. With a reduction of 40 decibels, normal speech is not audible and loud speech can be heard faintly, but cannot easily be understood, and such walls may be considered as relatively "sound proof." Partitions between apartments should have a factor of at least 40 decibels . . . the exact requirements will depend on local conditions."

Summarizing Mr. Close's conclusions, it may be safely stated that walls and partitions, to meet a good sound transmission loss standard, should be built of materials which will cause the finished wall to reduce sound transmitted through it by 40 decibels. The same thing holds true for ceilings under second floors. If materials and constructions have this acoustical insulating efficiency, it will mean that only the unusual and excessive noise, such as a shout, a radio turned on extra loud, or a dropped object will be heard in other rooms—provided, of course, that doors and windows are closed. The acoustical efficiency of any wall is reduced practically to zero if there is an unprotected opening in it.

Table 4 presents a selection of test results for walls of various types of materials and constructions. For more details on these tests, and for tests of many other types of constructions, the reader is referred to BMS 17 and its two supplements.

decay resistance, insect and rodent proofness

No standard inner wall material is waterproof; there is no particular need that it should be. It is not the function of an inner wall material to keep out the rain, or even to be *completely* resistant to leaks caused by faulty plumbing or inadequate window or chimney flashing or roof shingling.

It is important, though, that a material be strong enough so that it will not simply dissolve and fall in a wet mass or a weighty sheet of material when weakened by such exterior or interior leaks. This porousness and weakness is one of the most serious defects of plaster, but when plaster is applied over a strong paper-encased gypsum lath the danger of the plaster being so damaged by moisture that it may fall is considerably less than when wood lath is used as a plaster backing.

Though high moisture resistance is not an important desideratum in a wall or ceiling material, resistance to decay and to attack by termites, rodents, and other small deer that are prone to infest residences is a matter of considerable consequence to the home owner. There is no scien-

Table 4: Sound Transmission Loss in Typical Wall Structures
(Wood stud frames used in all panels listed)[1]

Panel description	Sound transmission loss, average over 128 to 4096 sound cycles per second.	Sound transmission loss, average over 256 to 1024 sound cycles per second.
Wood lath, scratch and brown coats of lime plaster, smooth white finish. 15.6 lb/sq ft	42.1	
Wood lath, scratch and brown coats of gypsum plaster, smooth white finish. 17.4 lb/sq ft		40.9
½" Insulite applied to both sides, joints filled. 5.1 lb/sq ft		29.4
½" Insulite, scratch and brown coats of gypsum plaster, smooth white finish. 13.3 lb/sq ft		47.9
Gypsum lath nailed to studs, nails approx. 6" apart, scratch and brown coats of sanded gypsum plaster (½"), smooth white finish. 15.2 lb/sq ft	41.1	
Gypsum lath held an with special nails with large heads, nails driven between lath sheets; scratch and brown coats of sanded gypsum plaster (½"), smooth white finish. 15.7 lb/sq ft	47.7	
Gypsum lath attached to studs by spring clips, scratch and brown coats of sypsum plaster (½"), smooth white finish. Weight not given	51.8	
Perforated gypsum lath attached to studs with clip consisting of coiled spring and piece of heavy wire extending across face of lath and interlocking with adjoining clip; scratch and brown coats gypsum plaster ½" thick, smooth white finish. 16.4 lb/sq ft	48.3	
⅜", 3-ply plywood both sides, light cotton fabric glued ta one side, heavy cotton duck to the other. 4.57 lb/sq ft	31.1	
¼" plywood glued to 1" by 3" studs, ½" plasterboard nailed to both plywood faces. 6.6 lb/sq ft	40.4	

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(1) Except where noted, studs are standard 2" x 4" in size.

tifically reliable method of establishing standards in materials for this sort of protection, both because materials themselves differ so greatly in their condition and susceptibilities, and because construction techniques play a so much greater part in insuring protection from these enemies of the house than do the materials themselves.

Perhaps the best rule to follow inside the house, where the dangers of decay, termite and rodent attack are much less than in the outer layers of the inner walls, roofs, and floors, is to avoid using materials that are notoriously subject to this kind of hazard, and otherwise to make sure that the outside construction of the dwelling is so tight that the inside automatically will be safe. Inorganic materials, though they may tend to disintegrate when moistened, will not rot; neither are they susceptible to attack by insects or rodents. Organic materials, on the other hand, in general disintegrate less quickly when damp, but will decay; they are also the foods of choice, so to speak, for termites, rodents, and the like. As rules of thumb these facts have some value; but they cannot be translated literally into practice; otherwise no wood ever would be used in residential construction!

Woods and other organic building materials can be protected against this kind of hazard by painting and by special types of treatment sometimes necessary in areas where the problem is known to be acute, particularly when the materials must be either in contact with, or close to, the sources of the hazard — the ground, basement walls unprotected by termite shields, and so on. There are on the market several especially treated woods for use in climates where decay and termite attack are serious hazards; and also some manufacturers of the lightweight insulating fiberboards claim that they have protected their products from these hazards by special patented processes. These claims may indeed be true, but in the absence of impartial and scientifically conducted tests, they must be viewed with some scepticism. Particularly to be borne in mind is the statement (from the Department of Agriculture's Farmar's Bulletin No. 1911, page 27, edition of 1946) that "Brush, dip or spray treatments usually give only very slight penetration and, consequently, only slight protection. Such superficial treatments usually do not add more than 2 to 5 years to the life of seasoned wood and are of little or no value where green material is used." Deep, integral penetration by pressure methods or by actual mixing during the manufacturing process—particularly in the case of pulp boards and the like—is the only sure method of protecting organic wall materials from these house hazards.

With this, the review of performance standards for inner wall materials is completed. In the following paragraphs let's make an analysis of the various types of materials used for wall surfaces from the point of view of the standards outlined above.

In the selection of materials for inner walls of a house—not, however, for their finish, since this review is not concerned with paints or wallpapers—the architect has an important function vis-à-vis the home-building client, whether he wants a house for himself, or is building a large subdivision. Few are the clients of whatever type who have the time, the desire, or (dare we say) the intelligent patience to want to analyze the various performance qualities of materials, and to evaluate them, first in terms of original cost versus maintenance costs, and second in terms of performance versus appearance.

Unfortunately, few architects have heretofore been able to give the necessary time to such a study. The net result has been that materials, and particularly wall materials, have more often than not been selected on purely subjective basis: popularity, advertising claims, conventionality, custom, price, immediate availability, or even personal friendship with the distributor of the material in question. However, in view of the marked differences in performance between the various types of materials, it is extremely important for the architect to know something of the nature of each material so that he can judge its usefulness in any situation he may be confronted with.

It is as a consequence of this situation that the following data on materials is perhaps fuller and more detailed than ordinarily would be considered necessary. Some of the facts will seem to some of the architect-readers of this review to be "common knowledge"; but the intention here is to present an essentially complete, brief guide to wall materials, even though some of the facts may seem obvious and trite. This guide is organized in terms of the standards outlined previously in this article, and also considers the various materials as components of more complex wall cross-sections to which each of several materials may add their own peculiar qualities.

types of wall materials for walls and partitions inside the home

In brief, interior wall materials fall into two major classes and several sub-classes. The two major divisions are, of course, the wet wall and the dry wall; the plastered wall versus the wallboard wall. Plasters may include standard gypsum or lime materials with or without a finished lime white coat, portland cement plasters, and stuccos. Exposed masonry walls sometimes are used as an inner as well as an outer surface, and they then may be said to fall between the two classes: part, the brick or block, is dry and another part, the mortar, is wet. Among the dry wall materials are gypsum wallboards, vegetable fiberboards of both insulating and noninsulating types, plywoods and solid wood panels, various types of masonry, and single thickness walls such as Durisol, Cemesto, and Kaylo.

Plaster laths, as analyzed in this review, include only the gypsum lath and insulating fiberboard lath. Wood laths are so rare today in most parts of the country as to be nearly obsolete. Metal laths, while essential as a base for bathroom tiles set in portland cement and certainly effective as a base for any type of plaster, are so much more expensive than the gypsum lath, both as a material alone and as a user of up to twice as much plaster as the gypsum or insulating fiberboard materials, that they cannot compete in ordinary residential construction. This is true despite the fact that, according to the National Bureau of Standards, they result in a wall which is much less prone to cracking than one built with a gypsum or fiberboard lath, and that a metal-lathed wall has a fire resistance factor which is somewhat greater than that of one lathed with gypsum.

Despite these factors, metal lath is uneconomical for any building situation where gypsum or fiberboard lath can be used. This is not, of course, to say that metal lath should not be used in residential construction. It is perfectly satisfactory when so employed. The fact is simply that it is not an economical material when placed in a wood frame structure.

Presented below is a summary of the various wall materials commonly used in residential construction and discussed in this review:

Gypsum wallboard and lath
Insulating fiberboard and lath
Noninsulating fiberboard
Hardboard
Plywood
Solid wood panels
Asbestos cement wallboard
Single-thickness dry walls, such as:
Masonry
Glass block
Durisol
Cemesto
Kaylo laminated panels
The plasters.

gypsum wallboard

Gypsum boards (and lath as well) are made from a composition of fibrous gypsum (hydrous sulfate of lime) and other materials pressed into sheets and faced on both sides with thin, strong paper. The gypsum core is incombustible, and the paper facings are so thin that they present little or no fire hazard. However, these boards have an extremely low insulating value ("C" equals 2.60 for the ½" board), so that insulation must be placed between the studs and the ceiling joists or attic rafters wherever the home is exposed to severe winter climates.

For dry wall application, gypsum boards ⅜" and ½" thick, 48" wide, and from 6' to 12' long are available. The edges are recessed, so that the joints between the boards can be concealed by pressing a thin, strong tape set in a special compound into the recess, and covering it with a neatly feathered coat of the same compound. Gypsum dry wall constructions are of two types: a single ½" thick gypsum board, or two layers of ⅜" boards, the first of which is nailed to the studs and the second glued over the first. The latter type of installation is of course more expensive than the former, but it also is more stable and resistant to cracks and joint separations due to the shrinkage of the framing members. The double-thick dry-wall gypsum wall is competitive with regular lath and plaster in most parts of the country.

A ½" gypsum dry wall on wood studs has, according to the Bureau of Standards, a 40-minute fire resistance rating, thus nearly meeting the fire safety standard set forth previously, which is ¾ hour. When applied over an incombustible (mineral wool) fill insulation, the rating rises to 45 minutes; over mineral wool batts nailed to the studs a one-hour rating is achieved. All types of application, therefore, meet or nearly meet the minimum fire safety standard.

Unfortunately, the Bureau of Standards has not published acoustical insulation tests for a gypsum wallboard wall on wood studs, so that accurate data on this aspect of its performance cannot be presented here. It probably does not meet the 40-decibel sound transmission loss standard described previously, at least in the single thickness, ½" installation. The performance of gypsum lath and plaster as acoustical insulation is given later on in this review.

Data on the strength of a gypsum wallboard wall is also unavailable at this time, but there is no reason to believe that it would not meet any standards established for residential construction. Certainly it is acceptable from the point of view of sharp impact resistance (hammer blows, picture nail tearing), since the paper covering is extremely strong.

Gypsum wallboard, like any inorganic material, is proof against decay and also against attack by termites, other insects, and rodent attacks. It will, however, deteriorate if constantly exposed to moisture. Consequently it must at all times be protected against exposure to exterior elements or interior leaks.

gypsum lath

This most commonly used plaster base is available, as everyone knows, both in plain and perforated styles. The perforated lath usually costs no more, and is to be preferred at all times to the plain, since the Bureau of Standards fire tests show that it adds roughly 15 minutes to the wall's fire resistance rating because of the stronger bond made between the lath and plaster. A plain gypsum lath and plaster wall rates 45 minutes; a perforated gypsum lath, and plaster wall rates one hour.

As remarked above, no gypsum or lime products have any thermal insulating value to speak of. Some unperforated gypsum laths are being offered currently with an aluminum foil on the back. Foil-backed gypsum lath has definite insulating value and has the same value under winter conditions as it has in the summer when the direction of heat flow is reversed —if an air space is provided. On page 110 of *Heat Insulation*, by Prof. Gordon B. Wilkes of M.I.T. the author asserts: "If an air space is faced on one side with a reflective surface, it makes no appreciable difference on which side the reflective surface is placed as far as the rate of heat transmission is concerned."

Although the question of joints is a difficult one—as it pertains to foil-backed gypsum—experts agree that properly installed foil-backed gypsum lath will meet allowable standards for vapor transmission. The United States Gypsum Company has stated that objective tests have shown that even with an actual crack between the laths there will still be less vapor transmission than is permitted by acceptable allowable standards.

When gypsum lath is nailed directly to the studs and plastered, an acoustical efficiency of roughly 39 decibels sound transmission loss is achieved—just about the minimum standard of 40 decibels. However, if the laths are fastened with broad-headed nails hammered between rather than through the pieces, the decibel reduction efficiency reaches a 45-decibel rate; and if they are attached with certain types of spring clips, it rises to nearly 52 decibels. In all instances the plaster is ½", three-coat gypsum and lime.

Though a gypsum lath-and-plaster wall was not tested by the Bureau of Standards for strength, there can be no doubt of its meeting the necessary strength required. Pragmatic experience over many years has proven that.

vegetable fiberboards

Three types of organic fiberboard are commonly available today: insulating boards and lath, low in density and light in weight; medium density boards, unsuitable for use as lath, heavier than the first type, and of not quite as high an insulating value; and the hardboards, dense, tough materials, as hard or harder than most woods, and (when specially tempered) sufficiently waterproof for use as low-cost sink tops and for other water-resistant purposes. Hardboards, too, are not suitable as plaster bases.

Practically all of these boards are made from pulped or chopped wood fibers, chemically treated in various ways. The exceptions most frequently found today on a national distribution basis are Celotex, which is made from bagasse, or sugar cane fiber, and Homasote, Upson Board and Beaver Board, all largely or entirely made from repulped waste paper. Boards made from other vegetable fibers such as palmetto, corn stalks, licorice roots, and so on, may be available in certain localities, but none of them is at present distributed nationally, and none has been examined during this study.

Insulating vegetable fiberboards are made of loosely compressed fibers felted into sheets of thicknesses ranging from ⅜" to 1". The ⅜" thickness is usually called a "utility" or "thrift" board, and is not used as a substitute for any of the standard insulations. The ½" boards are called insulating wallboards or lath, weigh about 0.7 pounds per square foot, and are available in a number of sizes and shapes, such as ceiling tiles, wall planks, and standard 4' wall panels, the latter two coming in various lengths. Planks and tiles usually are factory prefinished; panels are available both finished and natural.

The 25/32" insulating boards are used for sheathing, and are manufactured only with some sort of asphaltic treatment, either integral or surface, which adds to their weatherproofness. One-inch boards are simply two ½" boards laminated together; they are used when a greater insulating efficiency is desired.

All ten of the leading brands of insulating fiberboard are practically identical in physical qualities and in forms available. Consequently the summary of performance qualities given below applies, within very narrow ranges, to every standard insulating fiberboard on the market, no matter what the brand name.

The great appeal of the insulating wallboards is their dual function: they not only serve as an interior wall finish, but also, when used in combination with the 25/32" insulating fiberboard sheathing, as fairly adequate insulation for the walls of homes built in all but the most severe climates. According to data in the Housing and Home Finance Agency's *Manual on Wood Construction for Prefabricated Houses*, a wood frame house with ½" insulating wallboard and 25/32" insulating fiberboard sheathing and yellow pine lap siding will develop roughly 0.157 as a "U" factor. This means that the wall has a heat loss of 0.157 Btu per square foot of wall area per hour per Fahrenheit degree difference between outside and inside temperatures. A frame house using gypsum lath and plaster on the inside, 1" of mineral wool insulation between the studs, and 25/32" wood sheathing, building paper, and yellow pine lap siding on the outside, develops a "U" factor of 0.128. Thus the insulating fiberboards when used both as wallboard and as sheathing, do provide insulation at least in the same general range of efficiency as a 1" mineral wool batt. The uninsulated frame wall used as a guinea pig in these studies had a "U" factor of 0.243, which is about the kind of heat loss experienced in wooden houses previous to development of insulating materials.

As far as fire safety goes, the insulating wallboards are of practically no value whatsoever. Bureau of Standards figures for walls covered with fiberboard weighing 0.7 pounds per square foot of ½" material indicate an ultimate fire resistance rating of only ten minutes. The combustibility of these boards can of course be reduced by lining the studs and ceiling joists against which they are to be placed with heavy asbestos paper, asbestos cement boards, or thin gypsum lath. Although the actual surface of the wall will still be combustible, the danger of fire spreading through a wall into another room will be markedly reduced by such a precaution. Its cost, of course, will be much higher than that of the insulating wallboard alone.

The acoustical insulating qualities of the fiberboards are indicated, in the Bureau of Standards BMS Report 17, only by tests of one trade-marked material. A plain partition of wood studs with ½" fiberboard panels on both sides was reported as having a decibel reduction efficiency of only 29.4. When plastered with a standard ½" gypsum plaster, the acoustical efficiency rises to nearly 48 decibels, making the combination acceptable.

Strength tests for insulating wallboards can in general be only pragmatic, in view of the absence of adequate test data. The few boards tested and reported on by the Bureau of Standards in special numbered BMS monographs compared fairly well with a wood lath and plaster wall, as is indicated by the data in Table 1.

However, all insulating fiberboards have a soft surface which is relatively easily dented or broken by a sharp blow, and a lack of cross-section strength which permits corners or edges, where exposed, to be damaged quite easily.

One limitation common to all organic wallboards and laths is their lack of what is called "dimensional stability." Fiberboards tend to expand and contract measurably with changes in humidity inside the house, as do the softwoods until they have dried out. For example, if a fiberboard is installed during a dry spell, with the boards butted closely against each other, they may buckle slightly when the atmosphere becomes damper and the boards absorb moisture and expand. For this reason it is recommended that insulating board products of all types be installed with small cracks, roughly 1/32" in width, between each piece, particularly if the weather is dry when the panels are put in place.

All fiberboards are susceptible to a greater or lesser danger of attack by decay organisms, insects such as termites, and rodents. Certain trademarked products are said to be wallboards is their dual function: treatments, but as was pointed out before these claims must be taken with a grain of salt in the absence of impartial and independent tests.

In actual practice, the insulating wallboards seem to be most useful for finishing areas in basements or in attics, or for low-cost remodeling of rooms with damaged plaster. In these installations, at least when the boards are placed against incombustible backings as in the case of a basement wall or a damaged plaster surface, their low cost, fair insulating value, and ease of installation makes them very attractive to the home owner, and not a serious fire hazard. Whether they have any appeal to the architect in search of wall materials with good all-round physical properties is something each individual practitioner must decide.

Fiber insulating board lath was critically examined by the Bureau of Standards in its report BMS 3 (1938). The major difficulty encountered was the lack of dimensional stability of the lath under changing conditions of humidity. This resulted in some instances in as much as 0.05" buckling across a 16′ span. In a series of tests involving plastering of the lath, it was found that three-coat plaster was preferable to a two-coat job. Furthermore, a quick-setting plaster was much better than a slow-setting type, since "with the slow-setting plaster the buckling of the lath resulted in uneven surfaces and cracks along the points, even with strong plasters." (See page 7, BMS 3.)

It was also pointed out that oversanded plasters were unsatisfactory, and that "strong, quick-setting plaster ⅝" thick was satisfactory, but when the thickness was only ⅜", cracks developed in some instances along the horizontal joints of the lath after the panels had been dried."

Consequently quick-setting, strong plasters, applied at least ½" thick in three coats were recommended, the scratch coat being 1:2 gypsum plaster and sand by weight, and the brown coat 1:3.

The performance qualities of an insulating fiberboard lath and plaster wall are indicated by the following figures: 35 minutes ultimate fire resistance period, as against the 45-minute recommended standard; thermal insulating efficiency, slightly better than with the insulating fiberboard alone—a conductance of 0.60 for ½" lath and ½" plaster, as against 0.66 for the lath alone; acoustical insulation efficiency 47.9 decibel sound transmission loss, well above the standard of 40 decibels; strength data probably the same or better than with the unplastered insulating fiberboards; decay and pest resistance also probably somewhat better than with the plain board.

The noninsulating vegetable fiberboards, with a thermal conductivity rating of between 0.42 and 0.45 per inch of material, are not so very much less efficient than the insulating wallboards, which have conductivity factors ranging from 0.33 to 0.38 per inch. However, since they are no more than ⅜" thick, their actual net insulating value is not large enough to warrant their use without batt or fill insulation between the studs and joists wherever winter climates are severe.

As stated before, Homasote, Upson Board, and Beaver Board are all primarily waste paper products. Homasote is an integral board; Upson and Beaver, in wallboard thicknesses, are 6-ply laminated sheets. They all have somewhat higher tensile and nail holding strength than the insulating boards, and a slightly greater dimensional stability. The Bureau of Standards gives wallboards weighing 1.1 pound per square foot (the ones listed weigh even more) a 15-minute fire rating, as against 10 minutes for the insulating boards. Consequently the fire safety of the non-insulating pulp boards is not significantly greater than that of the lighter materials, with the possible exception mentioned below. No specific tests of any of these materials for acoustical insulation have been reported by the Bureau of Standards.

Perhaps the greatest advantage of Homasote and Upson Board is the fact that they are available in huge, room-sized panels measuring up to 8′ by 14′ over-all. This means that it is possible to finish an average-sized room with no joint or, at the most, one on each wall. It also may mean that a wall so finished will have a slightly higher fire resistance rating than mentioned in the previous paragraph, since the wall surface is monolithic, and has no cracks or joints through which the flames can spread. No actual tests have been made to prove whether there is anything to this supposition, but it at least remains logically reasonable that it should be so.

The integral pulpboard, Homasote, must be wetted overnight before applying so that full expansion of the material may be achieved; when this wetting is not done the results are catastrophic. Homasote may be simply nailed or, better, glued and nailed to the studs and ceiling joists. It has an easy surface to decorate which, however, cannot be plastered, as was mentioned earlier.

The big Upson Board sheets are fastened by means of special floating hangers which are nailed to the studs and joists, and to which the 8′ by 14′ panels are attached by light blows with a mallet or other nondefacing tool. In experience, Upson Board makes effective dry walls which can be painted or papered, or even left untreated, since it comes with a factory finish suitable for a finished wall. It, too, cannot be plastered.

The hardboards are dense, hard, non-insulating and practically nonwarping woodpulp boards which are used most often to make cabinet and closet sliding door panels and also, in low cost dwellings, to finish or refinish kitchens and bathrooms. For the latter purpose, the material is made with a tile-scored surface which can be painted with enamel paints. The hardboards have also been used as regular wallboards, most often to create the effect of a dado or wainscot around the lower part of a room, but sometimes to finish the whole wall surface. The hardboards have roughly the same fire resistance as the hardwoods, and consequently, since they cannot be plastered, are not acceptable for use as a 45-minute fire rating material, particularly in the thin sheets currently available. They are somewhat stronger than other fiberboard products and are, relatively speaking, moisture proof and resistant to insect and rodent attack except under unusual circumstances.

Hardboards are available in thicknesses ranging from ⅛″ up to 5/16″; the type specifically designated as wallboard is 3/16″ thick, and comes in panels measuring 4′ by 8′, 10′, and 12′.

Plastic wall surfaces, such as Marlite (which is a decorative finish factory-applied to a Masonite base by the Marsh Wall Products Company, a subsidiary of the Masonite Corporation) and Micarta, Formica, and the like (which are thicker and more durable versions of a plastic-finished wall surface, most commonly laminated to plywood) cannot serve as wall materials themselves, but must be supported either by a hardboard or a wood or plywood backing. Consequently they are classed here as wall finishes rather than wall materials, and are not included in this review. The same holds true of the various types of tile used to finish bathrooms, kitchens, and (sometimes) more formal rooms in homes. All require a plaster, cement, or dry wall backing, and cannot count as a separate and independent wall material.

plywood

There is no need to go into any detailed description of the plywoods, since every architect is familiar with their merits and qualities. On the plus side are plywood's beauty, particularly when the hardwood plywoods are used; its great strength and durability; and its low maintenance cost if the wood is left natural and not painted, but only waxed. Plywood also, due to the nature of the glues used to make it, is less susceptible to attack by insects and rodents than some of the other materials that have been described.

The minus aspects of plywood as a material for residential walls include the high price of the hardwood plywoods and the fact that the softwood plywoods, though less expensive, are not usually attractive enough for use undecorated. The striated fir plywoods are beautiful, of course, unpainted as well as painted, but their cost is higher than the plain. Most important performance defects of the plywoods in the home are their poor acoustical insulating qualities —only 24 to 25 decibel sound transmission loss—and the fact that they are combustible. Both of these factors can be somewhat minimized by applying an underlayer of ⅜" gypsum lath or wallboard to the studs and ceiling joists, and placing ¼" plywood panels over the gypsum. This is an expensive technique, but it does raise the acoustical insulating efficiency of the wall to over 40 decibels and adds half an hour or more to the fire resistance of the wall.

solid wood panels

In general, solid wood paneling is outside the economic range of most prospective home owners except, perhaps, for the "knotty" pines, cedars, firs, and other softwoods, which sometimes are used for finishing basement rumpus rooms, upstairs studies or dens, or even highly informal living rooms. They are somewhat less stable than the plywoods, since they have no cross-grain layers at right angles to the surface grain, and are also more subject to attack by biological enemies of the house, since they contain no glues of the sort which, in plywood, offer some protection. The fire resistance rating of a ¾" tongue and groove board wall is only 20 minutes, obviously below the 45-minute standard. However, well dried and well installed softwood paneling can be very attractive in the home, and offers the same compensations of low maintenance and replacement costs that plywood does. Wood paneling can be protected against fire and given added acoustical insulating value the same way that plywood can, by adding gypsum lath as an underlayment against the studs and bottoms of the ceiling joists.

asbestos cement wallboard

The only commonly used nonwood wallboard beside gypsum is made from asbestos and cement, pressed into thin, rigid sheets of great surface hardness but considerable brittleness. Although one would expect that such a board would have a high fire rating, Bureau of Standards tests indicate that a partition faced on both sides with 3/16" cement asbestos board has an ultimate fire resistance period no greater than that of the insulating fiberboards, or 10 minutes. When placed over ⅜" gypsum wallboard, however, the rating rises to one hour for the two materials in combination—much the same results as were posited for plywood underlayed with a similar thickness of gypsum board. It is true that the asbestos cement board is incombustible, but under extreme heat the material tends to disintegrate because of its brittleness, unless backed by the gypsum board.

The board is, of course, nonwarping, easy to clean, insect, rodent, and rot proof, and water resistant. These factors make it worthy of consideration in certain installations, though not commonly in living rooms or bedrooms. The material is available scored to imitate tiles, and also in special waxed finishes which are well adapted to use in bathrooms and kitchens.

single thickness dry walls

There are three general types of materials suitable for "single-thickness" walls in modern homes: brick or stone masonry or cinder or concrete blocks; special insulating glass or masonry units; and sandwich materials. None of these materials is exactly standard in residential construction, but all are, in certain climates and under certain conditions of construction, suitable for any kind of wall, interior as well as exterior.

Exposed masonry walls, both in all-masonry houses and in frame homes with large fireplaces, are becoming more and more common in homes designed along modern lines. Although excellent in every other respect—acoustical insulation, fire safety, decay and house pest proofness, and strength, these walls are, unless specially constructed, a source of considerable heat loss and dampness, since masonry is a poorer insulator than any other building material. In regions where heat loss in winter and dampness at any time are serious factors, masonry walls built in two vertical layers separated by an air space—the so-called "cavity wall"—are the best, though a very expensive solution for the heat loss problem, particularly when the cavity is filled with an incombustible insulation. The result is just about the most fool-proof wall that can be built. The problem of dampness will be minimized if not entirely dissipated by the use of the insulating material in the cavity space, especially if an impermeable waterproof membrane is applied to the outer surface of the inner layer of masonry.

Masonry partitions, used most often in homes where fire safety and resistance to fungus, insect, and rodent attack are considered important factors, may be built of brick or cinder block, unplastered if desired, or of gypsum blocks or structural clay tiles. The latter two usually are plastered, since the appearance of the rough blocks is not as pleasant as that of well-laid brick or cinder block. The thermal conductivity factors of these materials are very poor; however, that fact is of no importance when they are used as inner partitions, for they serve no function as barriers to cold. Their fire resistance ratings are well over the minimum of 45 minutes, except that the four-inch clay tile *must* be plastered to meet that requirement.

When plastered, all of these materials in the four-inch thickness have sound transmission loss factors well within the safety range, though certain types of exceptionally lightweight blocks do test a few decibels below the standard of 40. It is advisable to select units that are as solid as possible, i.e., that have the smallest hollow cores and the greatest density of material, both for acoustical insulating efficiency and for fire safety. Unplastered, none of the materials mentioned, except brick, are effective from the acoustical insulating point of view.

Economically speaking, of course, most masonry partitions cannot compete with the standard stud, lath, and plaster wall, though some architects have found that four-inch cinder block partitions, unplastered, are cheaper.

Insulating masonry units are of two general types—a special cement or concrete, and glass block. Recently put on the market is an insulating concrete block called Durisol. It is made with chemically-treated wood chips and shavings mixed with a lightweight concrete aggregate. In the 3⅜" thickness for exterior walls, it has a "U" factor of 0.20, which compares not too unfavorably with other materials. The blocks are incombustible, strong, dimensionally stable, decay and termite proof, and have good acoustical qualities. The inner face can be plastered if desired, or can be left unfinished in rough installations. Special studs are required between each vertical row of blocks, which may add considerably to the cost of a house built of this material.

Glass blocks, which under many circumstances are used only for decoration or in place of a window, nevertheless have fair performance qualities as a single-thick wall material. They are much better heat insulators than plain glass, having a "U" factor of approximately 0.40 in the smooth-faced types. This makes them unsuitable for general wall use if heat conservation in the winter is a factor, but quite effective where vision is not essential but light from outdoors is.

The sandwich materials mentioned above are known under the trade names of Cemesto and Kaylo Laminated Panel. Cemesto, made of up to 1½" of Celotex as a core with asbestos cement laminated to both sides, is said to provide adequate thermal insulation for most uses, with a claimed "U" factor for the two-inch panel of 0.16. It is stated to be "fire retardant," though the actual fire test data presented in the manufacturer's literature cannot be compared with standard A.S.T.M. tests. However, the data presented are sufficient for justifying the assumption that Cemesto is not anywhere nearly as combustible as the Celotex which composes its core. The edges of the panels are sealed on the job to prevent moisture, decay, and termite attacks, with a paraffin which forms as impermeable coating. Cemesto cannot be plastered, and for this reason, as well as for its generally unconventional appearance, it may not ordinarily recommend itself for individual houses. However, when skillfully used it may result in considerable first and maintenance cost savings and can prove very attractive in certain types of specially-designed modern homes.

The Kaylo Laminated Panel is made from a calcium-silicate core which has fair insulating qualities and is incombustible. The claimed "U" factor for the 1⅞" thick panel is 0.30, making it, on the record, considerably less efficient in this respect than the Cemesto board. However, its fireproofness, freedom from danger of attack by termites, rodents, and decay organisms, and dimensional stability make the material very acceptable for uses where high insulating values are not of paramount importance. The Kaylo panel costs somewhat more than Cemesto, at least at present while it is still not distributed through dealers but only direct from the manufacturer, but this situation may change in the future.

plaster

Traditional rough plaster is made from a mixture of lime or (more usually) gypsum, sand aggregate, water, and occasionally some kind of vegetable or animal fiber to give it cohesiveness, ordinarily in the first or "scratch" coat only. The brown coat is fiberless. The third, or white coat, is made of a very thin coat of lime putty mixed with plaster of paris and water, and serves only the purpose of ornament. A perfectly satisfactory wall surface can be achieved with scratch and brown coat alone, if the brown coat is carefully finished. The result will not be quite as smooth as a lime-finished wall, but it is still acceptable in many instances, and will mean a sizable saving.

Since plaster is a mineral substance, it is proof against decay and the attacks of termites and rodents, although rats will gnaw their way through plaster if they think the reward on the other side is large enough. As was shown in the early part of this review (see page 194, for wall strengths), an old-fashioned wood lath and plaster wall is stronger than all types of dry wall tested. On gypsum or insulation board lath, it probably is as strong, if not stronger, than on wood lath; however, to the author's knowledge the National Bureau of Standards has not released any tests on these types of wall, so the question cannot be specifically answered one way or another.

Acoustically, plaster usually increases the sound transmission loss of any wall, whether of wood lath, gypsum lath, or insulating lath, to a point well above the 40 decibel efficiency which the experts state is desirable in residential construction. Special types of lath installation may be necessary to achieve this efficiency, as pointed out earlier in this review, but even when merely nailed, the gypsum lath and plaster wall has a relatively high sound transmission loss factor.

More important than any other quality, in some ways, is the fact that a gypsum plaster wall in nearly every instance has a fire resistance rating of better than 45-minutes, usually better than an hour. The only important exception is when it is used on insulating fiberboard, when the rating is only 35-minutes, according to the Bureau of Standards. (Another exception is when wood lath are used, in which case the rating is only 30-minutes. However, wood lath are so nearly obsolete as not to warrant consideration in this review.)

Against these positive qualities in favor of plaster are the following negative factors. Plaster adds tons of water to the structure, at least until the house is thoroughly dried out, and this often means unhealthily damp conditions for months after the dwelling is built. It must be papered or painted, resulting in a constant, lifelong maintenance cost which is avoided when certain types of self-finishing dry wall materials are used. It is subject to injury from sharp impact and from picture nails, and difficult to repair neatly when holes are punched in it. It is particularly weak when wetted by leaks and unless protected by a strong wallpaper may fall away from the wall or the ceiling when constantly dampened, creating a very real accident hazard in the home. Plaster suffers from a lack of flexibility, too, and will crack whenever the frame of the house shrinks or settles, creating unsightly conditions which are costly and difficult to repair. And it costs more than the more common dry wall finishes, such as gypsum wallboard and insulating fiberboard.

Two recent changes in plaster technology have added to the material's desirability, without markedly increasing its cost. The first is the advent of the lightweight plaster aggregates; the second the discovery of importance of eliminating unhydrated oxides from limes used in white-coat plasters.

The enormous growth in the use of the lightweight aggregates instead of sand—vermiculite, perlite, and similar materials—has resulted from the various ways in which they make plaster easier to apply and better as a wall material. Vermiculite and perlite result in a much lighter plaster, easier to install, more uniform in quality, and entirely independent of the vagaries, chemical and physical, which local sands so often produce in plaster walls. The aggregates weigh less than one tenth as much as sand, and are absolutely uniform, always resulting in the same kind of plaster mix if the original proportions in the mix are the same. Furthermore, the lightweight aggregates raise the thermal insulating value of plaster to a respectable degree, giving the material about three times higher an efficiency as an insulator than a sanded plaster. They also considerably reduce the danger of plaster cracks and holes, since it has a resiliency which sand lacks. On the other hand, according to the Bureau of Standards, the lightweight aggregate plasters have in the neighborhood of two to three decibels poorer efficiency as an acoustical insulator than a sanded plaster—a limitation small enough to be relatively insignificant, but still a limitation.

Although lightweight aggregates cost between two and three times as much as the sand they replace, many plastering contractors are able to profitably use this type of material at the same over-all installed plaster price as for the sanded plasters, because so much labor time is saved.

The second important technical advance in plasters, which affects the white coat materials, concerns the discovery by the Bureau of Standards that white-coat discoloration, blistering and failures, often occurring years after the walls and ceilings have been in place, are due to the presence in the limes of a considerable percentage of unhydrated oxides. These oxides gradually absorb moisture from the air over a period of years and weaken the surface until failure results. The Bureau has developed a minimum standard for lime plasters, based on its extensive tests, requiring that no lime contain more than eight percent unhydrated oxides, and the lime industry currently is offering such limes in special bags marked with an "S" brand. All architects specifying white coat plasters should require the use either of these "S" branded limes, or of limes with less than eight percent of unhydrated oxides. The latter is perhaps preferable, since a number of limes manufactured in this country naturally contain less than eight percent of the unhydrated oxides, among them all high-calcium hydrated limes and most of the highly-hydrated dolomitic limes.

conclusion

The place of plaster in the modern hierarchy of housing values has long been in dispute. Dry wall enthusiasts preach that its friability, its susceptibility to cracks and to disintegration when wet, the extremely large amount of water it brings into a house when new, and its added cost, all have served to make it obsolete in modern technical thinking. The fact that it requires regular maintenance and redecoration is also pointed to as an economic liability.

Proponents of plaster point to the fact that it produces an absolutely smooth and seamless surface; that it is traditional and consequently gives a plastered house a better and a higher resale value; and that its esthetic qualities in general make it superior to dry wall constructions, particularly those which are competitive in price.

Spokesmen on both sides of the argument, in neglecting to assay the performance of the various materials in the light of the standards set forth in this review, are actually telling only half of the story. When examined from the point of view of fire safety, acoustical insulation, resistance to decay bacteria, insect and rodent pests, and even strength, the merits of plaster seem to grow larger than its demerits, particularly for economical construction in homes where stability and safety are worth a few extra construction dollars, but where there is no budget for luxury.

On the other hand, it is important to point out that all the evidence is not yet in. We have no data from the Bureau of Standards, or any other reliable and independent testing agency of which the author has knowledge, as to the performance qualities of gypsum wallboard either in its single or double thickness, except for its thermal conductivity and its fire resistance, and here the data are only for the ½" single-thickness material. Adequate tests for decay, termite and rodent resistance, and standards against which to measure a given material's specific performance along these lines, have never been developed. No material has ever been adequately tested for sharp impact or for the damage done by picture nails driven into the surface; the few tests of nail-holding strength which Standards has performed were not designed to measure this sort of damage. In other respects as well our information regarding some of the most important performance qualities of some of the most popular materials used for inner walls is either seriously incomplete or entirely lacking.

Streamlined Specifications: Interior Marblework

BY BEN JOHN SMALL

1. general:
- (a) Applicable provisions of "General Conditions" govern work under this Section.
- (b) These specifications are of the abbreviated or "streamlined" type and include incomplete sentences. Omissions of words or phrases such as "the Contractor shall," "in conformity therewith," "shall be," "as noted on the drawings," "according to the plans," "a," "an," "the," and "all" are intentional. Omitted words and phrases shall be supplied by inference in the same manner as they are when a "note" occurs on the Drawings. Words "shall be" or "shall" will be supplied by inference where colon (:) is used within sentences or phrases.
- (c) The Contractor shall provide all items, articles, materials, operations, or methods listed, mentioned, or scheduled on the Drawings and/or herein, including all labor, materials, equipment, and incidentals necessary and required for their completion.

2. work included:
- (a) Furnish labor and materials to complete interior marblework indicated, as specified herein or both.

3. conditions at building:
- (a) Marble subcontractor shall report to Architect (through Contractor) any conditions which prevent him from performing his work properly.
- (b) Assign marble subcontractor, without charge, adequate storage and working space for carrying on his work.
- (c) Furnish without charge to marble subcontractor:
    1. Necessary scaffolding.
    2. Required safety barricades or weather enclosures.
    3. Adequate hoisting facilities during regular working hours.
    4. Water, light, and power at convenient locations on each floor.
    5. Temporary heat.
    6. General cleaning of building.
    7. Telephone facilities.

4. kind, surface finish, location:
- (a) Marble: as specified; conformed to or within approved sample range and in accord with characteristics and working qualities set forth under their respective group, A, B, C, or D, in "Handbook for Use of Interior Marble," issued by Marble Institute of America, Inc.
- (b) Exercise care in selection to produce as harmonious effects as possible. Patch and wax marble carefully where permitted under Marble Institute of America Group Classification in manner to conform to general character and finish of marble.
- (c) Surface finishes: sand rubbed or wet sand finish, grit finish, hone or eggshell finish, polish finish, as indicated and specified.
- (d) Marble in various spaces: (List in detail trade names of marbles and/or alternates, and finishes selected, and spaces where used. Describe extent of marblework required or reference may be made to "Schedule of Finishes.")
- (e) Plaster of Paris, Portland cement, and White Portland cement: A.S.T.M. Standards.
- (f) Sand: clean, free from organic and other deleterious matter likely to stain finished work; screen as required for desired results.
- (g) Portland cement shrinkage reducing accelerator (used with Portland cement to give cement quick setting characteristics of Plaster of Paris): non-staining admixture that will not corrode anchors or dowels.
- (h) Plasticized bonding cement (used in place of plaster or cement): plasticized synthetic resin base that will not stain thru marble; is unaffected by temperature changes or moisture; adhere with strong suction to clean surfaces.
- (i) Calking mastic (for setting and pointing): non-staining, knife consistency, elastic, moisture-proof.
- (j) Anchors, dowels or cramps: brass, copper or aluminum. Use special cramps, dowels and the like where indicated on shop drawings; elsewhere install ordinary wire anchors as indicated by building conditions.
- (k) Cushions (to maintain joints, especially where non-staining mastic is used): aluminum or clear plastic.

5. samples:
- (a) Submit samples of various kinds of marble proposed for use. Samples: 4" by 6" or 8" by 12", represent approximate shade, marking, characteristics of variety of specified marble and finishes required. (Where required to show variations in color and markings, submit larger samples or range of samples.)
- (b) Label samples on back; designate finished face, building name, kind of marble, group classification, Contractor's name.

6. models:
- (a) Where models are required for ornamental carving, they shall show work in full scale, be furnished by others and delivered to marble subcontractor's plant without charge.

7. carving:
- (a) Execute carving with skilled workmen, in accord with approved full size details or models. Drawings indicate approximate depth and relief of carving.

8. interpretation of drawings and specifications:
- (a) In case of discrepancies, dimensions take precedence over scale sizes; large scale or full size details supersede small scale drawings; specifications prevail over all drawings.

9. measurements (for separate contracts):
- (a) If measurements are not established and guaranteed in advance, marble subcontractor shall obtain and verify measurements at building.
- (b) Lend all reasonable assistance to marble subcontractor, including services of engineer, if required, for establishment of levels and the like.

10. shop drawings approval:
- (a) Submit shop and setting drawings of work specified herein.
- (b) Full size details shall show sizes, sections, marble dimensions, jointing, bonding, anchoring, connections with other work, other required details.

11. standing marble and molded work:
- (a) Standard thickness for marble where one face only is finished: approximately ⅞"; returns of jambs, pilasters and the like: ⅞", unless otherwise specified. Install joints closely, not to exceed 1/16".
- (b) External angles shall have butt joints, unless otherwise specified.
  (Quirk miter joints should be indicated and specified; use only above base.)

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* *Associate, Alfred Hopkins & Associates, Architects. The author acknowledges gratefully the assistance of the Marble Institute of America, Inc.*

(c) Cut molded work accurately to indicated profiles. Minimum thickness at thinnest point of mold: ⅞″.

(d) Set marble by spotting with Plaster of Paris (see note below) and with concealed setting wire anchors secured in wall backing. Install anchors in sufficient quantity to render installation secure. Butter joints fully with Plaster of Paris as each slab is set.
(Standing interior marble where moisture may be a factor, and marble used as exterior veneer, should be set with anchors in conventional manner as above, spotting with Portland cement plus accelerator. Such marble should have joints buttered fully with accelerated cement or buttered with non-staining mastic as each slab is set. As an alternate, use plasticized bonding cement; spot back of marble and wall with plasticized bonding cement; push marble into place. Ordinarily no wire anchors are necessary. Marble so set must be supported from below to prevent movement in shear.)

12. base and plinths:

(a) Base: ⅞″ thick unless otherwise indicated; extend 1″ below finished floor line. Where marble border is indicated, set base on top of border.

(b) Plinths: as indicated, set on top of finished floor.

13. floor marble:

(a) Others will install rough concrete or cinder fill above floor slab to within 2½″ below finished floor line. Clean floor thoroly; fill wet with clean water before laying mortar bed. (See alternate below.)

(b) Size, tile, and border pattern, and jointing of floors; as indicated; ⅞″ thick, unless specified otherwise.

(c) Cement bed to receive tile: 1 part Portland cement to not more than 3 to 5 parts of sand mixed quite dry for tamping; spread over rough fill. (See alternate below.)

(d) Tamp marble tile with suitable mallet until bedded firmly to proper floor level.

(e) Remove and back parge tile with wet cement or sprinkle bed with water and cement. In latter procedure, wet tile back. Method of buttering tile edges fully as it is laid is acceptable.

(f) Joints between tile: 1/16″ when finished.

(g) Rope off floor for 24 hours; grout with water and neat cement or grout by buttering tile edges as they are laid. Clean surplus joint cement from tile face immediately.

(h) Clean and surface floor with floor surfacing machine after it has set at least 6 days.
ALTERNATE for paragraphs (a) and (c) if 2½″ or more is available:

a-(alt.) Others will install rough concrete or cinder fill at least 2½″ below finished floor line. Spread tar paper or thin bed of clean, well screened sand over rough fill so that there will be no bond between tile bed and fill. (This manner of installation provides barrier against transmission of ground moisture at grade level and makes cracks in floor due to structural movement less likely.)

c-(alt.) Cement bed to receive tile: 1 part Portland cement to not more than 3 to 5 parts of sand; spread over paper or sand bed.

14. saddles (thresholds):

(a) Flush saddles: approximately ⅞″ thick by jamb width.

(b) Raised saddles: (1¼″) (1½″) thick, rounded or beveled as detailed.

(c) Notch saddles occurring between steel jambs to jamb profile. Run saddles, occurring between wood jambs, under door stops.

15. window stools:

(a) Marble window stools: (plain, polished edge) or (molded nosing); furnished where indicated (on window schedule) or (at window openings in plaster or tile walls); set securely in place. Where practicable, install in one piece; if joints are necessary install joint at mullion centres. Thickness: (⅞″) (1¼″).

16. stair marble:

(a) Risers and strings: ⅞″ thick. Extend risers from top of one tread to underside of tread above, butt string; anchor securely.

(b) Treads and platforms: (⅞″), (1¼″) or (2″); butt string. Make platforms, indicated in one piece and projecting to form nosing, same thickness as treads.

(c) Nosings: (plain) or (have nosing molded to detail). Where nosing is formed by separate piece, balance of platform may be ⅞″ thick.

(d) Bed in cement mortar treads and platforms on stairs of metal frame or steel pan construction.

17. toilet marble:

(a) (Assemble stiles and partitions with concealed dowel fastenings) or (secure intersections of stiles and partitions or partitions and walls with chromium-plated angles, 3 in height of stall.)

(b) Where toilet enclosures project from wall to allow for pipe space, others will furnish proper supports for marble.

(c) Extend water closet stall (5′-10″) or (6′-0″) high above finished floor.

(d) Stiles and screen partitions: 1¼″ thick (1½″ thick if used with heavy doors and coin boxes); extend at least 1″ below finished floor line.

(e) Partitions: ⅞″ thick, rebated into stiles ⅜″; extend thru backs.

(f) Set dividing partitions 12″ above finished floor; rebate into stiles not less than ⅜″; extend thru backs.

(g) Extend partitions 1″ into floor.

(h) Urinal stall partitions: ⅞″ thick and, if built to floor, extend 2″ below finished floor; recess into or extend thru finished wall.

(i) Others will furnish stall doors, door hardware and accessories.

18. shower and dressing stalls:

(a) (Assemble stiles and partitions with concealed dowel and cramp fastenings) or (secure intersections of stiles and partitions or partitions and walls with chromium-plated angles, 3 in height of stall).

(b) Extend shower and dressing stalls 7′-0″ above finished floor; recess 1″ into finished wall; furnish complete with marble wall linings and marble (or tile and terrazzo) floor slabs as detailed. Stiles: 1¼″ thick; partitions and wall slabs: ⅞″ thick.

(c) Install marble seats in dressing stalls, of indicated size and thickness.

(d) Rebate vertical slabs at corners; set into slot or rebate in receptor, as indicated.

(e) Joints, except as otherwise specified: 1/16″ thick; butter with litharge and glycerine or ⅛″ thick buttered with non-staining mastic.

(f) Others will furnish and install precast receptors.

(g) Where lead pan construction is required, pan will be furnished, formed, installed, and connected under "Plumbing Work." (Lead pan should be covered with suitable protection against chemical action.)
(h) Butter bottom, slab backs, and vertical edges that are rebated into marble faces with non-staining waterproof cement.
(i) Others will furnish curtain rods, curtains, all fittings and accessories.

19. marble templates: (a) Marble templates for water closets: ⅞" thick, as indicated.

20. center tops, check desks and deal plates: (a) Use marble of thickness and construction as indicated.
(b) Others will furnish and install backing or other supports for marble.

21. drinking fountains: (a) Provide drinking fountains as detailed. Others will furnish and install hardware for same.

22. columns, column enclosures and pilasters: (a) Use marble of thickness and construction as indicated.

23. cutting and fitting: (a) Co-operate fully with other trades; do such cutting and drilling to accommodate work of others as may be reasonably implied from Drawings and Specifications.

24. delivery and protection: (a) Pack marble carefully for transportation; take necessary precautions against damage in transit.
(b) Furnish, install, and maintain wood guards for protection of projecting members, corners, window stools, saddles and the like.
(c) Protect marble flooring with non-staining materials, against traffic, other damage.
(d) Protect marble adequately from paint, oil and other stains.

25. cleaning: (a) After completion of work and at such time as Architect shall direct, clean marble installation; point any open joints; replace any defective marblework.

NOTES TO JOB CAPTAIN

1. samples: (a) Marble is a product of nature; hence it is impossible to guarantee uniformity of color, veining or any other characteristic that may be represented in any particular sample submitted. A sample will indicate an average color and marking as well as the general texture and specified finish.

2. definition of surface finishes and uses: (a) Sand rubbed or wet sand finish is a smooth surface produced on a cast iron rubbing bed with sand and water. Used for treads, saddles, platforms, and floors; on floors by surfacing operation after setting.
(b) Grit finish is a smooth, dull finish between sand and hone, produced by grits. Used for treads, saddles, platforms, and floors; on floors by surfacing operation after setting.
(c) Hone or eggshell finish is a dull glass surface giving relatively little reflection of light; produced by a natural or artificial hone by hand work or machine. Used for treads, floors, and standing marble.
(d) Polish finish is a gloss surface that will reflect light and emphasize color and marking of material, produced by a buffer with putty powder applied to a honed surface. Generally used for standing marble.

3. thicknesses: (a) Standard thickness. Unless otherwise indicated or specified, the standard thickness for marble, where one face is finished, is accepted by the trade to be approximately ⅞" from the saw. Finishing processes will reduce any thickness slightly.
(b) Floor tile. Commercial floor tile are approximately ⅞" thick. Standard sizes are 8" x 16", 12" x 12", 10" x 20"; the tile ordinarily are supplied 1/32" scant of standard nominal size in each dimension in order to produce the usual 1/16" joint when laid in floor. Other sizes are classed as floor slabs. In designing a pattern floor, the different varieties of marble selected should have similar wear characteristics.
(c) Molded work. In molded work, the minimum thickness at the thinnest point of the mold should be ⅞". This minimum thickness may have to be increased, depending upon width or height of molded work in question.
(d) Thick slabs. When thicker marble slab work is required, as for counters, sanitary partitions, etc., standard sawing gages produce approximate thicknesses of 1¼", 1½", and 2". (Avoid 1", 1⅛", 1¾", or other intermediary thicknesses where economy is important as these are special and disproportionately costly.)

4. measurements: (a) The progress of any contract can be expedited if measurements can be established and guaranteed in advance. Otherwise the marble subcontractor must delay fabrication until conditions at building enable him to secure measurements. The method of predetermined measurements not only hastens the work, but if established for all trades, reduces costs and prevents many errors.

5. setting materials: (a) Plaster of Paris, Portland cement, litharge and glycerine have been used in standard practice by the trade for years. All such materials should conform to and meet all requirements of standard specifications of A.S.T.M. for each of the above mentioned materials.
(b) Plaster of Paris "SPOTS" (a term used in the trade) are used as backing for standing marble. For ashlar work and smaller pieces these spots are usually sufficient if applied around the location of anchors only. For larger pieces, such as wall panels, spots are usually applied between top and bottom joints in addition to those around anchors. No fixed rule should be given as to the number of spots; this should be left to discretion of marble subcontractor. (Some newer developments in setting materials are described herein. The mention of a brand should serve only as a standard and should not be construed to exclude other materials that have shown results equally satisfactory in long term laboratory tests and field installations and otherwise comply with the requirements.)
(c) Portland cement and shrinkage reducing accelerator. Plaster of Paris is soluble in the presence of moisture and it is not suitable for spotting or jointing on exterior veneer, in shower stalls, in unheated mausoleums, or whenever dampness may be present.
Portland cement and shrinkage reducing accelerator, equal to Sika #C, manufactured by the Sika Chemical Corporation, can be used like Plaster of Paris and will be permanent where moisture is a factor. It is economical

and equal or superior to all other setting materials listed and will be permanent even where moisture is present. Sika #C is usually mixed in a proportion of 1 part Sika #C to 5 parts of water mixed with Portland cement. This mortar has a setting time that allows enough time to set marble in proper position and at the same time quick enough so that minimum support of slab is required. The dilution mentioned may vary depending on type of cement, temperature, and setting time required on each job.

(d) Plasticized synthetic resin bonding cement. This is a black or dark mastic material, impervious to moisture, not affected by heat or cold, that adheres with a strong suction to all clean surfaces without sagging, and sets to a stiff plastic state, not brittle, not hard, but capable of absorbing moderate shock or settlement. It will not "bleed through" a stain on ⅞" marble. Damage to wall backing and expense of spoilage of drilling marble are eliminated, since normally no anchors are necessary in setting vertical marble 2" or under in thickness in this manner. It is especially desirable where setting space is tight or at points where anchoring is difficult. Cushions may be required in joints to avoid movement in shear. This material should be equal to Vermont Bonding Cement, distributed by the Vermont Marble Company.

(e) Elastic non-staining pointing and calking mastic. It is now possible to secure white and gray elastic pointing or calking mastics that are compounded to combine long plastic life and non-staining characteristics. If properly installed, these knife-consistency mastics remain plastic for a long period of years and produce an impervious and elastic joint. They are recommended for buttering joints of thin marble, exterior veneer or ashlar and store fronts and for interior shower stalls, etc. The greater the mass the longer will the mastic retain its plasticity. Buttered joints should be at least ⅛" to 3/16" thick. Superficial pointing of a small joint is of little permanent value. There are also available red and black mastics compounded to be non-staining on dark decorative marbles. Never use cheap, oily mastics or linseed oil putty on marble. Mastics should be equal to those distributed by:

Tremco Manufacturing Company.
Pecora Paint Company.
Vermont Marble Company.

(f) Plastic or aluminum cushions. These are available in 1/16", ⅛", and 3/16" thicknesses and recommended to maintain uniform joints in marble assembled with non-staining mastic where the weight of the marble might force the mastic out of the joint. On light-colored marble, never use wood or lead cushions which may stain.

(g) Integral waterproofing. When casting concrete floor slabs it is important, especially at ground level, to densify concrete to stop transmission of moisture through floor surfacing material. Concrete should be densified by others and made water-resistant by use of integral waterproofing.

6. miscellaneous setting suggestions:

(a) Setting space (a term used by the trade) indicates distance from rough wall backing to finished face of the marble.

(b) Normally 1½" is the minimum setting space. Where reinforcing liners may be required, 2½" setting space should be allowed.

(c) Concealed anchors and dowels are copper, brass or aluminum wire, approximately ⅛" in diameter.

(d) Joints should be buttered fully with joint material, colored, if specified. Superficial pointing of joints after installation is not satisfactory.

(e) Ceiling marble that must be supported by special anchors requires a space not less than 3" back of the marble. Supports and anchors must be sufficiently heavy and numerous to prevent sagging.

(f) Plaster work above marble should be in place before marble installation starts. Otherwise there will be a back charge by marble subcontractor for special protection.

(g) Marble should not be set directly against unpainted structural steel, piping, reinforcing, etc.

7. toilet room and shower construction:

(a) Only such hardware necessary for erection of marble should be included in the marble specifications. This should be chromium-plated brass or any non-staining metal.

(b) Stall doors and all accessories, although ultimately attached to marble, should be supplied by others.

8. framing or wall supports:

(a) All backing and supports required by the marble subcontractor should be furnished and installed by others.

9. external corners:

(a) Unless otherwise specified or indicated, it is accepted by the trade that butt joints should be used. That is, the exposed return of the member should be the accepted or specified thickness of the member.

(b) Another method of treating external corners, especially where only the minimum thickness of marble is required, is what is commonly called a "quirk miter joint." This method involves more labor and it should therefore be distinctly specified when desired.

(c) The quirk miter joint is not recommended for base as this construction forms an unsanitary internal angle at the floor; also, there is more danger of chippage. The use of butt joints is distinctly preferable where members extend to the floor.

10. non-slip inserts and nosings:

(a) It is now possible to have installed either on new work in marble subcontractor's plant or at the site on old work, non-slip inserts and nosings or over-all applications of non-slip inserts. This is recommended for preventing undue wear on stair treads, revolving doors, ramps, etc., and to reduce slip hazards.

(b) The following materials have been used successfully:

Martex: American Abrasive Metals Company.
Natalon: National Grinding Wheel Company.
Non Skid: Non Skid Surfacing Corporation.
Tru-Tread: Vermont Marble Company.

11. maintenance note:

(a) Decorative marbles selected for exterior veneer require cleaning and reasonable maintenance for continued good appearance and therefore should be treated at least once a year with a spray of cellulose acetate or similar plastic lacquer.

Resilient Flooring Resume

BY DAVE E. SMALLEY

Since the advent of linoleum, many years ago, there has been a steady increase in the popularity of resilient flooring. Within the last decade or two, however, the idea has taken on revolutionary proportions.

The most applicable definition which Webster gives to the term *resilient* is "a body capable of withstanding sudden shock without permanent deformation or rupture." Therefore, floors of a resilient nature have these advantages over permanent, hard, nonresilient floors: they yield to pressure, providing greater comfort underfoot; indentation from pressure is self-remedied; they are more sound absorbent and quieter under impact; and they are easier to replace. These desirable factors, along with spectacular improvements in decorative effects, are responsible for the great and growing popularity of resilient floorings.

In the following pages we attempt to describe and discuss briefly the several types of resilient floors. It is to be understood, of course, that we must more or less generalize since the products and recommendations of the several manufacturers are not identical. While the limitations of space prevent our differentiating between the various brands, we will try to be fair to all.

Of the generally recognized types of resilient floors, we have linoleum in its several classifications, cork tile, rubber tile, asphalt tile, and the newer vinyl plastics. Taking these in the order named, we begin with linoleum, the oldest of all and the one with the most variations.

linoleum

Basically, almost all linoleum made today consists of oxidized linseed oil, fine-ground cork and wood flour, color pigments, mineral fillers, and resinous binders. This mix is bonded under heat and pressure to a backing of burlap or felt. Although the designations differ somewhat among the different manufacturers, the several popular kinds of linoleum can be classified as plain, inlaid, jaspé, embossed, marbleized, and tile.

Plain Linoleum

Plain linoleum is the newer term for what was for years called "Battleship." In its darker shades and heavier gage it is still frequently referred to by the same name which was derived from the earlier use of this material on the decks of battleships.

As the term implies, plain linoleum is of one solid color. At one time as much as ½-in. thick, it is now rarely more than ⅛-in. in thickness. It is supplied in a rather wide range of shades but the browns, grays, tans, and greens seem to predominate.

The heavy gages are less adaptable in regions where the humidity is excessive, and this rule applies to practically all linoleum since the material is softened by long exposure to such conditions.

Because of its smooth, more-or-less impervious surface, its toughness and consequent wearability, plain linoleum is especially adapted for commercial and institutional use; for this purpose ⅛-in. gage is recommended. For residential and other moderate conditions 3/32-in. gage is recommended.

Plain linoleum is also used extensively for runners in corridors, where it is inlaid in terrazzo or concrete and is frequently used to border and accent custom-designed floors.

The rules for the installation and treatment of plain linoleum differ so little from those of the other kinds of linoleum that those features are discussed collectively in another section of this article.

Inlaid Linoleum

Straight inlaid linoleum is so constructed that the decorative pattern goes entirely through to the backing, thereby preserving the pattern intact during the life of the flooring. It is made by two different methods, one of which is cutting the designs out of different colored strips of linoleum mix, with dies similar to biscuit cutters. These sections are automatically combined in the general design on the backing. Heat and pressure then complete the process.

Molded inlaid is made by sifting finely granulated mix, through a series of stencils, onto the backing material; followed by molding and fusing to the backing, under repeated applications of heat and pressure. Embossed linoleum is also made by this process with the addition of manufacturing processes by which parts of the design are depressed under heat and pressure, creating a textured effect.

Straight inlaid patterns range from simple straight-line styling to custom effects and are usually supplied in gages of 3/32-in. to 1/16-in. They are recommended for residential and light commercial use or, in conservative patterns, for offices and residential kitchens.

The embossed inlaid, usually made in tile and textured styles, offers wide opportunities to create unusual effects in commercial and residential interiors.

Some inlaids are lacquered and waxed before leaving the factory. This pretreatment is probably found beneficial because most inlaids have vertical pores, making the untreated flooring a little more absorbent to moisture and to traffic stains.

Jaspé Linoleum

Jaspé linoleum is similar to plain, except that it presents a multitone, striated appearance in a series of irregular, varying tones of the same or harmonizing color in more-or-less parallel streaks. It is supplied in a variety of colors though the greens and tans seem to be favored.

Somewhat more expensive than the plain, jaspé has these advantages over the latter: it avoids the monotony of a single plain color and its variegated effect helps to conceal footprints, dust, and small litter. It is also capable of being made into many decorative designs such as checkerboard, basketweave, herringbone, miter joint, etc.

Jaspé linoleum can be recommended for schools, hospitals, commercial buildings, and residences. In gage it is obtainable in ⅛ in. and 3/32 in. It is produced in rolls six ft wide and up to 99 ft in length.

Marbleized Linoleum

For all practical purposes there seems to be little difference between the texture and serviceability of marbleized and jaspé linoleums. The principle difference is in the design, the marbleized simulating the variegated, nondirectional pattern of marble. It is better adapted than jaspé for custom designing because it can be cut into various shapes without harming the pattern effect. Supplied in many patterns and shades, it is available in gages of ⅛″, 3/32″, and 1/16″ and is recommended for all types of interiors.

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* *Brazil, Indiana.*

Linoleum Tile

True linoleum tile, which is sold widely, is merely ordinary linoleum cut into tiles. It has, therefore, the same qualities as linoleum. However, certain linoleum-appearing tile products are processed differently, producing a product much more dense and durable than ordinary linoleum. This type of tile is said to have an indentation resistance of more than 200 psi which is nearly three times greater than that of regular linoleum. Therefore, it is much more than just linoleum cut into squares. It is exceptionally resistant to wear and abrasion and will not crumble or dust under heavy loads. Usually marbleized, the colors of which go through to the backings, it often so closely resembles rubber tile and asphalt tile that close inspection is required to identify it.

Supplied in squares of from 2″ x 2″ to 12″ x 12″ and in rectangles of from 3″ x 6″ to 18″ x 36″, it is recommended for all public buildings, including schools and hospitals, and for residences. The cost is about that of rubber tile.

cork tile

Cork tile, although it belongs to the linoleum family, differs from linoleum both in manufacture and structure. At one time made simply by compressing ground cork under high heat, the object being to melt the natural cork resins to serve as a binder, it was later found that excessive heat was injurious to the cork. Today certain resins of a lower melting point are used to eliminate the need of high temperatures; and in some cases dielectric heat has supplanted the oven-baking process.

Cork tile is not as durable as other types of resilient flooring and requires more careful maintenance methods.

Softer and more resilient underfoot than any other floorings, it is almost as noiseless as carpeting and exceptionally comfortable. It also possesses a rich dignity not found in other floorings and is particularly adapted for libraries, art galleries, courtrooms, reception rooms, and richly appointed residences. It is often used in banks, where it serves well in tellers' cages.

Since it is cellular in structure, cork tile is virtually impervious to air and atmospheric moisture. It will not warp and is subject to a minimum danger of rotting.

It is sometimes necessary to sand a new installation of cork tile to remove the unevenness at the joints caused by irregularities in the subfloor. However, where the beveled tile is used sanding should not be necessary.

Cork tile is usually supplied in the following sizes: 6″ x 6″, 9″ x 9″, 12″ x 12″, and 24″ x 48″. In gage it runs 3/16″ and 5/16″ although some manufacturers supply it in other thicknesses.

Of the various popular types of linoleum, certain comments and information apply to all.

linoleum and cork tile maintenance

All linoleum products, being largely or wholly comprised of vegetable matter, are vitally affected by alkali. Soap is made by combining vegetable oils or fats with alkali; therefore, when linoleum is brought into contact with alkali, especially if the latter is activated by moisture, a process similar to saponification begins. For that reason clients must be warned about the use of alkaline cleaners on linoleum.

But there is much more to the alkali hazard than the use of cleaning agents, at least from the standpoint of the architect. Linoleum, including cork tile, must never be installed over damp concrete or concrete which may become damp. This means that no linoleum of any kind should be laid on a concrete floor in direct contact with the ground—especially in below-grade installations where dampness in concrete is almost certain to exist at some time. There is a natural alkali inherent in concrete which, though much slower in action, can eventually be as effective as lye.

As a matter of fact, all authorities with whom this author is acquainted recommend that linoleum be laid on suspended subfloors, where there is ventilation underneath.

In order to insure the best service from linoleum or cork tile, an owner or supervisor should be instructed in the proper care of the floorings. While the manufacturer usually provides such instructions there are some basic facts that the architect should know.

As already indicated, no cleaner of an alkaline nature should be used. Only neutral soaps (those containing not more than 0.15% free alkali) are recommended, though certain synthetic cleaners (sulfated alcohol or sulfonated hydrocarbons) may be used with safety.

Finishes of a varnish or lacquer nature (those applied at the factory excepted) should not be used since they tend to stiffen the flooring and make it brittle. Floor waxes are the only kind of finish that should be used for the maintenance of linoleum and cork tile and all manufacturers of these floorings approve them. On linoleum either the solvent or water-wax type may be used, though for the original treatment of cork tile two or three applications of the solvent type are recommended, after which water waxes may be used.

rubber tile

From the standpoint of original cost, rubber tile is the most expensive of resilient floors. This fact, coupled with those which give it exceptional beauty, richness of sheen, clearness of colors, and the luxurious "feel" underfoot, have justified the frequent reference to rubber tile as the "aristocrat of floors."

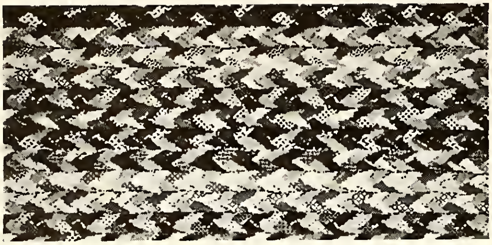
These rather superlative qualities especially recommend rubber tile where an air of elegance is desired, such as in exclusive shops, executive offices, and fine homes. It is also very adaptable for hospitals, clubs, libraries, and schools. Naturally less slippery than some other floors, it is especially suitable for entrance ways.

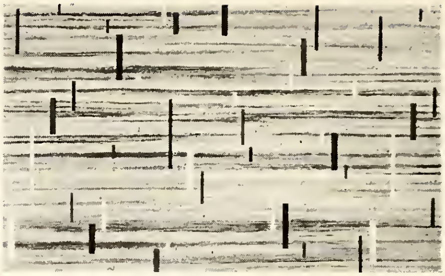
Originally natural rubber was used in the manufacture of rubber tile but World War II compelled manufacturers to resort to synthetic rubber. This substitution proved to be a boon, since it was soon found that the synthetic rubber possessed better wearing qualities and less tendency toward oxidation (the "death" of rubber) and made possible the control of quality. Uniformity of product, never completely accomplished from natural raw materials, has been established in the manufacture of rubber tile.

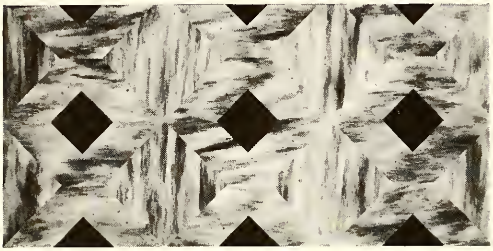
One of the special advantages of rubber tile is its high resistance and its prompt recovery from indentation. Compared to the

linoleum

inlaid linoleum





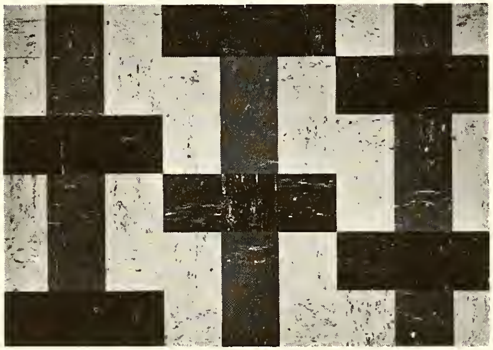


Straight-braid design in linoleum; three possible color combinations (above, left).

Inlaid linoleum; colored "Jackstraw" strips set cross-directionally to striated background colors (above).

Brushed effect in linoleum pattern composed of 6⅜" x 6⅜" and 8½" x 8½" blocks with 3⅛" x 3⅛" insets; gray or brown background, yellow, red, taupe, or green insets (left).

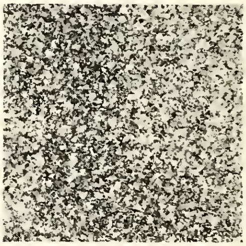
Photos: Armstrong Cork Co.; Congoleum-Nairn Inc.
Pabco Products Inc.



Staggered design in rubber tile (above); *available tile sizes are 6" x 6" and 9" x 9".*

Color and marbleization extend through thickness of these rubber tiles (below); *26 colors.* Photos: B. F. Goodrich Co.
American Biltrite Rubber Co.

cork



Natural-shade cork tile (above); *gages: 3/16" and ⅛"; tile sizes: 9" x 9", 6" x 12", and 12" x 12".*

Photo: Sloane-Blabon Corp.

rubber tile

resistance of other types of flooring, rubber tile will stand up to 200 psi, whereas 25 psi is considered the limit for asphalt tile, 40 psi for cork tile, and 75 psi for plain linoleum. Rubber tile is, in addition, much more resistant to cracking or crazing and its high-tensile strength prevents excessive contraction and expansion, thus eliminating any tendency to buckle.

As it is the most pliable tile flooring (vinyl tile being a possible exception), rubber tile will conform to smaller irregularities in the subfloor and to minor swellings or settlings of the latter.

Rubber tile can be satisfactorily installed, however, over any smooth, firm floor of concrete, steel, well-seasoned wood, or other hard surface. Of course the floor surface must be free of dust, oil, grease, floor wax, and other foreign matter.

Concrete subfloors must be absolutely dry before installing the tile and this particularly applies to freshly-laid concrete. A simple way to test the dryness of the concrete is to sprinkle a small quantity of calcium chloride in the center of a ½-in. thick ring of putty (about 3 in. in diameter) on the floor. Press a piece of window glass over the putty ring to prevent the outside air from coming in contact with the chemical, the latter being visible through the glass. If there is any moisture or dampness in the concrete, the calcium chloride will dissolve and show water spots. If the chemical remains white and dry after eight hours, it is safe to proceed with the installation. This test may be utilized for testing the moisture in any floor since no flooring should be installed over any kind of damp subfloor.

It is not to be assumed that even such a successful test qualifies a below-grade concrete subfloor for an installation of rubber tile. Nor is it recommended that rubber tile be laid over concrete which is in direct contact with the ground. No matter how dry the surface of such concrete may be at the time, its hygroscopic qualities will eventually draw moisture out of the ground by the process of capillary attraction.

While most manufacturers of rubber tile warn against its installation on below-grade or ground-contacted concrete, at least one manufacturer seems to take issue with them. Or, at least, he recommends his rubber tile for basement floors. He says: "When proper precautions and preparations have been taken, rubber tile flooring can go into any basement at a very small additional cost—not more than 10 to 12 percent." Briefly, his methods are in the one instance, to place a tar, waterproof membrane over the primary slab, to tie it in with the side walls, and to continue up to a point above grade. Then both floor and wall are cemented over. "Where a basement concrete floor has been completed, the floor should be coated with tar; two by four sleepers are then placed, and a plywood subfloor is laid—leaving spaces around the edges for ventilation. Next, saturated asphalt felt is cemented to the subfloor and on this the rubber tile is installed with waterproof cement."

For architects and their clients who may not favor the foregoing method, we shall show later that asphalt tile is more easily adapted for below-grade subfloors and seems to be the more generally accepted material for the purpose.

Rubber tile also seems to serve best on suspended subfloors and in such cases presents no special installation problems. It does, however, call for special maintenance care to avoid damage to the flooring. Differing from linoleum, mild alkaline cleaners are even approved while the use of soaps is restricted by The Rubber Manufacturers' Association. The Association states in its recent cleaner specifications regarding alkalinity: "The pH value of a solution of the maximum concentration recommended for use shall not exceed 11.6." This permits the use of modified soda which is a 50-50 mixture of sodium carbonate and sodium bicarbonate.

Regarding the use of soap, the Association limits to one percent by weight the maximum concentration of anhydrous (dry) soap in the solution used.

Water emulsion waxes are recommended for maintaining all rubber tile and periodic buffing with No. 1 steel wool is suggested. Oils and greases, the hydrocarbons, are all enemies of rubber, bringing about its gradual disintegration. This means solvent-type floor waxes (liquid or paste) should never be used on rubber tile. Neither should oily dust-mops or sweeping compounds be utilized. Daily mopping with clear water and buffing with a floor polishing machine is the recommended routine.

asphalt tile

No type of resilient flooring has made such rapid strides in popularity as has asphalt tile. Once an unlovely material whose limited two-tone color scheme was sometimes referred to as "two shades of black," it has developed into one of the most decorative of floorings.

Now made principally or wholly of asbestos fibers, mineral pigments, and resinous binders it is capable of being made into all the rich and vivid colors of the other floorings.

It is not nearly as pliable or resilient as rubber or linoleum and unless it is warm, it will break before it bends. For that reason perfectly level, smooth, nonflexible subfloors are more important than in the case of any of the other resilient floorings.

Although its resistance to indentation is comparatively low, it is probably the toughest and most "foolproof" of all the floorings. Only certain solvents (such as gasoline, oils, greases) which quickly dissolve it seem to be the natural enemies of asphalt tile. Solvent-type waxes, including paste wax, are ruinous.

Being thermoplastic it softens under heat, but is relatively fire-resistant. It is the one type of resilient flooring which is recommended by all of its makers for below-grade installations and it can be used on concrete at any level.

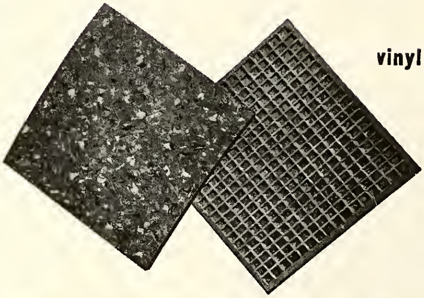
In the case of wooden subfloors, one manufacturer specifies that the floor should be double and composed of well-seasoned boards, not over 3 in. wide. He further specifies that "A layer of 15-lb completely asphalt-saturated felt paper with butt joints shall be laid across the boards and cemented down with linoleum paste. The felt paper shall be thoroughly rolled with a 100-lb 3-section iron roller."

In any case, there should be an underlayment of felt cemented across the wooden floor and it is recommended that the tile itself should be kept in a warm room for at least 24 hours before installation. During the laying of the tile a room temperature of at least 70 F should be maintained for easy handling of the tile and adhesive.

Asphalt tile is now supplied in a greaseproof type, designed for kitchens, automobile showrooms, etc., wherever grease or oil may be spilled. It is from 30 to 50 percent more expensive than standard tile and

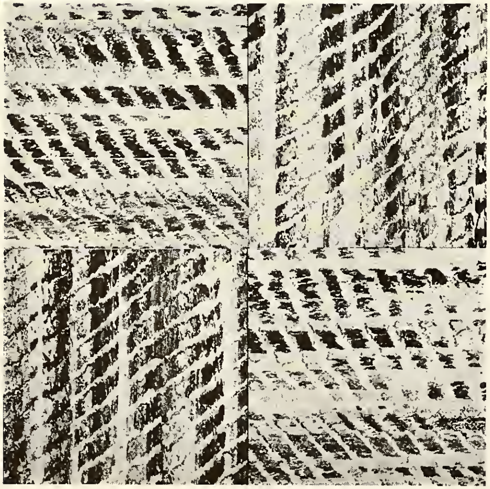
asphalt tile

Asphalt tile in confetti pattern of multi-color dots and dashes on solid-color background (left); *9" x 9" squares are 1/8" thick; 10 background colors.*
Photo: Mastic Tile Corp. of America



vinyl plastic

Terrazzo-pattern vinyl-plastic tile (right); *can be installed without use of adhesives.*
Corduroy-pattern vinyl-plastic tiles (below) *and a panel of vinyl-cork parquetry* (below, right).
Photos: Robbins Floor Products, Inc.
Bakelite Co.; Dodge Cork Co.



vinyl plastic

vinyl cork

therefore is recommended only where there is a specific need for it.

Nearly all types of soap and mild alkaline cleaners may be used for maintaining asphalt tile but to obtain best effects and to ease the cleaning it should be waxed, using a water wax, of course. But wax often makes asphalt tile slippery. This fact has given rise to the belief that asphalt tile is naturally slippery. However, according to The Asphalt Tile Institute, the National Bureau of Standards reports as follows: "Under most conditions asphalt tile is safer to walk on than any other smooth-surfaced material, provided it has no high-gloss wax finish."

This would seem to eliminate floor wax for the maintenance of asphalt tile but in the past year or so one of the large chemical companies has developed a solution of suspended, finely-ground silica which, when added to water-wax emulsions, increases as much as 50 percent the coefficient of friction. These waxes, now obtainable from many sources, seem to be the answer for waxing asphalt tile. Varnishes and lacquers are, of course, unsuitable and often detrimental.

Asphalt tile, usually about ⅛-in. gage, is now supplied in a wide range of colors and designs. It is adapted for use in almost any kind of building and is particularly recommended where cost is an important factor.

vinyl plastic

Vinyl-plastic floorings are just coming into general use and are supplied in both sheets and tiles. As flexible as rubber, they are said to be fairly immune to alkalies, oils, greases, and ordinary mineral solvents. Some makes contain asbestos fibers, others are made of vinyl resins and color pigments, modified with special plasticizers and calendered on felt backing. Some of the tile is molded into shape without a backing, so closely resembling rubber tile that one almost has to "smell" it to identify it.

Its chief attributes seem to be its extreme flexibility, rich colors, and fine natural gloss, though its cost is relatively high. Much is claimed for it by its producers but since it is still a comparatively new material, its wearing qualities over an extended period are yet to be determined.

Vinyl-plastic flooring may be used over practically any kind of dry, smooth subfloor, though only vinyl plastic asbestos tile may be used below-grade. It is recommended for markets, auto showrooms, laboratories, homes, and seems to be popular in drug stores. Tile sizes may vary but the standard seems to be 9″ x 9″ with ⅛″ thickness, though one authority claims more vinyl tile is used in 1/16″ thickness. Borders run 9″ x 9″ and 18″ x 24″.

A high coefficient of friction is claimed and waxing is pronounced unnecessary. However, since any kind of surface will finally succumb to friction, it is obvious that a protective coating of wax should extend the life of the flooring.

conductive flooring

While, in the foregoing, we have discussed the different popular resilient floorings as such, there is still something to be said about a certain phase of those floorings that has become important. Conductive flooring constitutes certain structural adjustments in the different types of flooring for the purpose of draining off static electricity.

In most cases conductive floorings are now compulsory where installations are made in the surgeries of hospitals and other locations where explosives are used or stored.

A few of the leading manufacturers of linoleum, rubber tile, and asphalt tile now supply their floorings with conductive qualities. In appearance and other visible characteristics they cannot be distinguished from the regulation floorings. But they must be specially maintained, avoiding the use of coatings which might nullify the conductive properties for which they are designed. An inquiry recently made of The Underwriters' Laboratories brought this reply, "We have listed no waxes or similar finishes for general use on conductive floors. Two manufacturers of ours listed electrically-conductive floorings supply finishing and maintenance materials which may be used on their own floors but these materials have not been tested and listed for general use on various types of floors."

radiant heating

In concluding this article on resilient floors there is something to be said in regard to their use over radiant heating installations. Since this type of heating consists of a series of pipes, often embedded in concrete floors, the same rules apply as already cited for the proper use of resilient flooring on concrete.

Therefore, if the concrete is in direct contact with the ground on or above grade, asphalt or rubber tile may be used. However, for below-grade installations only asphalt tile should be used. On suspended subfloors where the heating is located, linoleum may be used. Cork, rubber, and the vinyls may also be used in radiant-heating installations and are completely efficient for such use.

Because of the thermoplastic qualities of most resilient flooring materials, these floors tend to become slightly softer when radiant heating temperatures run higher than normal. However, since most radiant systems deliver normal temperatures of 75 to 85 F at the immediate surface of the floor, it is not considered any more effective than the direct rays of summer sunlight.

Near the beginning of this article the writer said that it would be difficult to abide by the specific descriptions and directions of all the manufacturers of resilient floors. Obviously we have been unable to do so but we have endeavored to give the architect-reader the general idea which cannot have gone too far astray from any one manufacturer's version. At least we have tried to be as fair with the makers of the floors as we have tried to be helpful to our readers.

acknowledgments

The following organizations, through their literature and personal help, have assisted greatly in the preparation of this article:

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Fremont Rubber Company
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The Goodyear Tire and Rubber Company
Johns-Manville
Kentile, Inc.
Mastic Tile Corporation of America
Pabco Products Inc.
R. C. A. Rubber Company
Robbins Floor Products, Inc.
Sloane-Blabon Corporation
United States Rubber Company
Uvalde Rock Asphalt Company

Streamlined Specifications: Asphalt Tile

BY BEN JOHN SMALL

1. general:

(a) Applicable provisions of "General Conditions" govern work under this Section.

(b) These specifications are of the abbreviated or "streamlined" type and include incomplete sentences. Omissions of words or phrases such as "the Contractor shall," "in conformity therewith," "shall be," "as noted on the Drawings," "according to the plans," "a," "an," "the," and "all" are intentional. Omitted words and phrases shall be supplied by inference in the same manner as they are when a "note" occurs on the Drawings. Words "shall be" or "shall" will be supplied by inference where colon (:) is used within sentences or phrases.

(c) The Contractor shall provide all items, articles, materials, operations, or methods listed, mentioned, or scheduled on the Drawings and/or herein, including all labor, materials, equipment, and incidentals necessary and required for their completion.

2. work included:

(a) Furnish labor and materials necessary to complete asphalt tile work indicated, as specified herein, or both, including:

1. Felt over wood subfloors.
2. Clean, wax, polish asphalt tile work.
3. Submit full-size duplicate samples of asphalt base and each type of asphalt tile in accord with "General Conditions."
4. Submit shop drawing layouts of tile patterns for space ———— in accord with "General Conditions."
5. See Deductive Bid for substituting (or) omission of asphalt tile flooring and base.

3. work excluded from this section:

(a) Extend asphalt tile only to kitchen and pantry dressers and not under same except into toe space.

(b) Stop asphalt tile at front of radiator enclosures and do not carry into same.

(c) Do not lay asphalt tile over fireplace hearths.

(d) Undercoating. See "Undercoating Flooring" section.

(e) Metal dividing strips at joint where asphalt tile floors abut and finish flush with cement, concrete, terrazzo, ceramic tile and ———— are specified under other sections. (Where stair treads are to be covered with asphalt tile, specify and detail metal nosing strips.)

MATERIALS

4. asphalt tile:

(If Schedule is used, size, colors, etc. may be omitted here.)

(a) Asphalt tile: FS SS-T-306a (or) made by one of following manufacturers ———— ————, factory waxed, ⅛" thick (or) 3/16" thick (always use over wood subfloor) 9" by 9", 12" by 12", 18" by 24". Asphalt tile: have calendered surface, contain no sand or grit, be equal to samples in Architect's office, with same factors of ductility, hardness, nonabsorbence, resistance to alkalis, acids and water, be free from lumps and unmixed coloring matter.

(For greaseproof asphalt tile use above specification inserting word "greaseproof" before asphalt tile and adding the following:

> Greaseproof asphalt tile: not soften in all animal and vegetable fats at normal room temperatures, shall comply with following test. Two tiles: cut into 6" by 6", be totally immersed in pure leaf lard for 24 hours at temperature of 77F plus or minus 2°. At the end of 24 hours, tile: removed from lard, wiped off with dry cloth. If surface of tiles shall have become softened, tiles represented by sample: considered to have failed. In determining whether or not surface of tile has become softened, tile: lightly scraped with spatula blade. Any separation of surface from body of tile when so scraped: sufficient evidence of softening.)

(b) Color: standard (or) marbleized; colors: as selected later (or) as per "Schedule of Finishes."

(For economy, select colors before awarding Contract. Colors are divided into 4 color groups designated as Group A, Group B, Group C, and Group D. The lowest cost is Group A and the highest is Group D. Group A contains plain dark colors. Group B contains plain medium colors and dark and medium background marbleized colors. Group C contains plain light colors and light background marbleized colors. Group D contains light plain colors, such as white, and light, such as white, background marbleized colors.)

(c) Carry borders of 6" to 9" widths around fields.

5. base:

(a) 3/16" thick, "set on" cove type with premolded smooth rounded top and cove base; (or) ⅛" thick, straight base, with premolded internal and external angles (or) internal and external angles formed on job; be sufficiently flexible to allow for slight irregularities in walls and partitions.

(b) Base: —" high (4", 6", or state any special height required).

(c) Base: made of same material as asphalt tile floor.

(d) Base color: standard black.

6. strips:

(a) Of same material as asphalt tile floor: be ——" wide.

(In multiples of ½" from ½" to 4". 1" and 1½" widths in 18" and 24" lengths. Other widths in 18" lengths.)

7. cement:

(a) Water-resisting asphalt cement: as recommended by tile manufacturer.

(Where asphalt tile floors are to be installed on concrete subfloors on or below grade, or on concrete subfloors where moderate amount of moisture may be expected, cut-back-type cement should be specified. Where asphalt tile floors are to be installed over felt or asphaltic underlayments, emulsion-type or cut-back cement should be specified.)

8. protective edgings:

(a) Stainless steel or aluminum alloy of approved design to protect exposed tile edges.

9. primer:

(a) Asphalt primer: as recommended by tile manufacturer; spreading capacity: 100 sq. ft. per gallon.

(Or)

(a) Asphalt primer: FS SS-A-701.

(Where asphalt tile floors are to be installed on concrete subfloors on or below grade, or on concrete subgrades which are new and may contain concealed moisture, cut-back-type primer should be specified. Where asphalt tile floors are to be installed over suspended concrete subfloors that have heated and ventilated spaces below them, cut-back-type or emulsion-type primers should be specified as options. Suspended concrete subfloors that are hard, dry, free from dusting and not porous do not require primer. Primer is never required over felt or asphaltic underlayments.)

10. lining felt (for use over wood floors):

(a) Lining felt: of type as recommended by tile manufacturer; not exceed 15 lbs. per 108 sq. ft.

11. samples:

(a) Do not start work until samples have been submitted and approved. Label samples stating color or shade, location in which they are used, manufacturer's name.

(b) Samples: finished with finish herein specified (or) unfinished.

(c) Installed materials: match approved samples.

12. delivery:

(a) Deliver materials to job in manufacturer's original unopened containers with manufacturer's brand and name clearly marked thereon.

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* *Associate, Alfred Hopkins & Associates, Architects.*

INSTALLATION

13. subfloor:

(a) Lay asphalt tile on subfloor of ______________. (State whether cement, concrete, wood, or undercoating. If wood, specify sanding of wood subfloors elsewhere.)
(For separate Contracts)

(a) Inspect subfloor before starting work. Notify Architect in writing of any defects in subfloor. Do not proceed until such defects as reported have been corrected. Starting of work implies acceptance by this Contractor of underflooring. Where cement-filled metal pan stairs or top of landing is covered with asphalt tile, depress fill for thickness of tile.

14. preparation:

(a) Fill subfloor cracks, expansion joints and the like with spackle or approved joint filler.

(b) Clean subfloor of grease or other dirt before proceeding.
(For separate Contracts)

(b) Subfloor will be delivered to this Contractor broom clean; clean subfloor of grease or other dirt before proceeding.

(c) Wood subfloors: double construction, sufficient structural strength to carry intended loads without deflection. Surface flooring: well seasoned, kiln-dried t & g flooring not over 3" face width, topnailed and toenailed. Surface floorings: sanded to uniform smooth surface; contain no cupped or spring boards. Nails: flush or set.

(d) Cement or concrete floors. Apply one primer coat to subfloor; when dry, trowel on cement, evenly, thinly, using not over one gallon to 75 sq. ft. of floor.

(e) Subgrade concrete floors. Coat concrete subfloors with liquid cut-back asphalt cement of brushing consistency.

(f) Old cement or concrete subfloors: made clean, free from floor coverings or other surface treatments. Remove paints from floors in direct contact with ground. Fill expansion joints and score marks with spackle or approved joint filler.

(g) Do not begin work until work of other trades, including painting, has been completed.

(h) Maintain rooms and subfloors at 70F minimum for at least 48 hours before, during, and 48 hours after tile applications.
(For use over wood floors it is advisable first to lay undercoating on wire lath, but in case of very smooth and rigid wood subfloors it is possible to lay asphalt tile over felt. Undercoating should also be used over rough concrete, gypsum, steel, or over old worn flooring of any type.)

15. felt:

(a) Cover wood subfloors with felt layer having butt jointed edges, staggered cross joints, cut carefully to fit around vertical surfaces, laid across joints of wood boards. Apply felt securely to subfloor with approved type linoleum paste. Roll felt into paste so as to remove air bubbles and ensure complete adhesion; use 150 lb. linoleum type roller. Roll edges and cross joints until firm adhesion is obtained; lay tile thereon. (Floors which have been undercoated do not require any felt lining or further preparation.)

16. laying tiles:

(a) Use only experienced workmen. Lay tiles so as to ensure good contact with close, even joints and with finished surfaces in true plane, smooth. Lay tiles square with room axis, with border width varying slightly to maintain full size tiles in field. Lay tiles to pattern selected with grain reversed in alternate tiles.

(b) Borders to fit neatly, into breaks and recesses, against base, around pipes, under saddles and carpet strips. Cut, fit and scribe borders to walls after application of field tile.

(c) Cut tile to and around radiator legs and heaters, or excessively heavy fixed objects. (Asphalt tile will extrude from around any fixed object; excessively heavy objects should rest directly on subfloor.)

(d) Install protective edgings, where tile edges are exposed, with flush screws spaced 12" apart; use expansion shields for screws in concrete.

(e) (For alterations only.) Where saddles or carpet strips are now in place, remove same, replace them when border has been laid.

17. laying base:

(a) Do not apply base until plaster, or backing material, is thoroughly dried out.

(b) Cement base firmly to wall.

(c) Form in and out angles neatly; scribe base accurately to trim at doors.

(d) Base throughout: have top, bottom edges in firm contact with walls, floors.

18. cleaning, waxing, polishing:

(a) At completion, clean tile work and base; remove cement, dirt, or other foreign substances.

(b) Apply two coats of wax; polish each coat to produce well polished finish.

(c) Do not permit traffic on finished floors unless they are protected with heavy papers.
(Asphalt tile when properly compounded has semi-rigid structure; any distortion from a level plane is best corrected by laying same and allowing to "seat" naturally.)

19. adjustments:

(a) Inspect and make necessary adjustments within one month of time that heat is supplied continuously on finish areas.

(b) Tiles that have not "seated" in level plane with surrounding tile: have heat applied locally, be quickly rolled to surrounding floor tile level. Repair tile, showing minor breaks and fractures, with heat and quick rolling.

(c) Tiles showing broken corners or fracture lines entirely across their surface: warmed, removed; substitute new tile of same color, thickness.

NOTES TO JOB CAPTAIN

1. wood subfloors: Asphalt tile shall not be installed over wood subfloors which are subject to conditions that might cause buckling or rotting of wood. This condition occurs generally on wood floors that are below grade, on grade, or above ground and without heat or adequate ventilation underneath floors.

2. magnesite subfloors: Asphalt tile shall not be installed over magnesite subfloors that are in direct contact with the ground.

3. use out of doors: Asphalt tile shall not be used out of doors or in areas that are not heated in cold weather.

4. prevention of indentation: All metal domes shall be removed from the legs of furniture and equipment. Suitable protective devices as recommended by the manufacturer furnishing the asphalt tile shall be used on furniture and equipment to protect against indentation. As a precautionary measure against indentation, lining felt as specified hereinbefore is recommended over wood floors.

5. use of one solid color: Where a single color is used in an over-all pattern, the possible lack of uniformity should be given consideration. This is particularly true in plain colors.

6. general: Asphalt tile is available in:

- Standard (plain, marbleized)
- Greaseproof
- Industrial
- Conductive

NOTES FOR INSPECTION PURPOSES

1. preinstallation inspection:

Type of subfloor	Inspect for	Floor should be
1. New concrete	Proper curing and drying. Moisture or dampness.	Free of expansion and trowel marks, grease, dirt, or foreign matter. Free of imperfections. Hard, dry, and nonpowdery.
2. New wood	Compliance with flooring specifications of maker as to construction in single, double, tongue and groove, and hardboard underlayment.	Smooth, dry, and free from grease, dirt, or other foreign matter.
3. Old concrete, terrazzo, ceramic tile	Soundness, dryness, and necessary repair.	Level, free from cracks, holes, paint, varnish, and other finish. Also free from dirt and other foreign matter.
4. Old wood	Renailing, replacement of worn or damaged boards, necessary filling of holes and cracks.	Sanded smooth, free of paint, varnish, oil, or other foreign matter.

2. installation inspection:

Type of resilient floor	Inspect during installation for	Check finished floor for
Asphalt tile	Symmetrical joint lines. Tight joints.	Over-all appearance. Raised joints.

ASPHALT TILE MAINTENANCE

1. "don'ts":

1. Don't use water or wax until the asphalt tile is thoroughly seated and until the adhesive has set up—about two weeks.
2. Don't clean asphalt tile with gasoline, benzine, naphtha, turpentine, or organic solvents. Organic solvents will soften the material and cause discoloration.
3. Don't expose asphalt tile to oils, greases, and solvent waxes such as paste wax.
4. Don't use oily soaps or cleaners on asphalt tile floors.
5. Don't use waxes containing turpentine, naphtha, or similar solvents.
6. Don't use sweeping compounds which contain oils, sand, or chemicals.
7. Don't apply wax over a dirty floor.
8. Don't apply varnish, lacquer, or shellac. They contain ingredients which are injurious to asphalt tile and also eventually will cause unsightly traffic lanes.

2. cleaning:

(a) New floors should not be washed or waxed until all the tiles are tightly adhered to the subfloor. This may require several days. If cleaning is necessary in this time, wipe up with a damp cloth or mop—not wet.

(b) When ready, clean the floors thoroughly, and apply a good grade of water emulsion wax. Several successive light coats are recommended.

(c) An occasional washing with a diluted warm suds solution of a good neutral soap or cleaner will keep floors clean and attractive. After washing, rinse thoroughly with clear water and when all traces of soap and dirt have been removed, dry with a clean mop.

(d) If ordinary washing fails to remove any stains, the surface of the tile should be rubbed lightly with #00 Steel Wool using a concentrated solution of neutral soap or cleaner and warm water.

3. waxing:

(a) The use of a good grade water emulsion wax applied in accordance with the manufacturer's directions is recommended.

(b) If a high lustrous sheen is desired, apply several successive light coats, buffing each coat after it has been allowed to dry thoroughly.

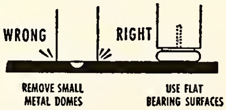
(c) DO NOT use waxes containing such solvents as turpentine and benzine, as they soften the tile and cause the colors to bleed.

(d) Grease and oils allowed to remain in contact with asphalt tile will permanently stain the floor. In case of spillage, wipe off immediately.

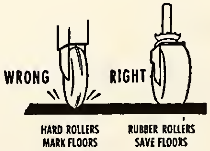
(e) DO NOT use varnishes, lacquers, shellac or other plastic finishes. These materials usually contain solvents that will permanently injure asphalt tile.

4. protective devices:

(a) For side chairs, light cabinets, etc., that are moved more or less frequently, glides having a smooth, flat base, with rounded edges and a flexible pin to maintain flat contact with the floor are recommended. The size should depend upon the weight to be carried. Such glides can be obtained in sizes from about 1" to 2½" diameter. *Small metal domes should be removed from the bottoms of all chair and furniture legs, and replaced with flat glides.*



(b) Easy swiveling ball bearing wide wheel casters, or flat guides, should be used on furniture that is moved frequently, such as desk chairs, etc. Casters should have large diameter wheels (2" or more) with wide flat soft rubber composition tread. Small diameter, narrow, hard wheel casters, particularly with a crowned tread and without ball swivels will unnecessarily and unduly mark all types of resilient flooring. For heavier furniture, such as pianos, trucks, hospital beds, etc., consult flooring contractor.



(c) Furniture cups are made of a composition material in a pleasing neutral color, designed to prevent the legs of furniture from cutting the floor. They are manufactured with openings 1⅓", 1¾", 2" and 2⅝" square, and also with round openings 1⅝" and 1⅝" in diameter. They are designed for use on heavier furniture that is moved infrequently.

The author acknowledges gratefully the assistance of the Asphalt Tile Institute in the preparation of these specifications.

SURFACE PROTECTION

If adequate measures are taken to protect and preserve their surfaces, most materials have infinitely better weathering qualities. Wood, obviously, is a prime example of such a material and because of this need the manufacture of both paint and wood preservatives have become great industries. Too often, however, paint for exterior wood is specified rather haphazardly even though serious consequences may be at stake. In the following article, J. S. Long points out that many specifications simply require that two coats of a particular brand, or equal, be applied and fail to insist that the *first* coat be designed as a foundation coat and that the *second* be designed as a rain and sun coat. He also points out that many home owners are the victims of house painters who, in an offhand way, may advise that "the entire house needs two coats of paint." Actually, a one-coat house paint (a relatively recent development in the paint industry) can be applied over old paint with satisfactory results.

In attempting to obtain an impartial evaluation of the various wood preservatives and methods of application that are currently being marketed, one receives a welter of conflicting prejudices. Pressure treatment? Soaking? Dipping? Brushing? Just try to find any agreement between manufacturers whose products require different degrees of exposure to be most effective. And for that matter, which preservative materials, commensurate with cost, are more suited for the various components of a house? In his discussion "Wood Preservatives and Preservative Treatment" (*page 223*), George M. Hunt, former Director of the U. S. Forest Products Laboratory, looks at the industry from a venerable vantage point and offers the reader an acceptable basis upon which he may form his own judgment as to which preservative and application method adequately fulfills the requirements of his special problem.

Brick and concrete masonry structures likewise benefit from a protective treatment. One of the most recent and satisfactory surface waterproofing materials has been developed from the silicone resins. F. O. Anderegg, of the John B. Pierce Laboratories and long a recognized specialist on building materials, presents his findings after performing research on a typical silicone product in "Research Report: Surface Waterproofing With Silicone Resins" (*page 227*).

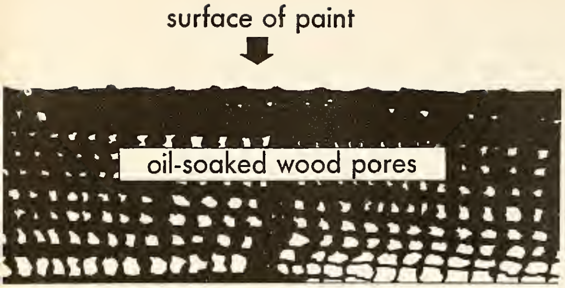


Figure 1

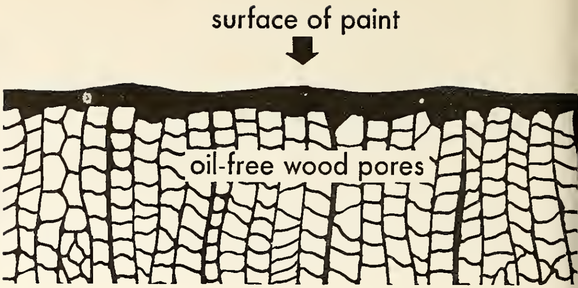


Figure 2

Do You Specify Paint Properly?

BY J. S. LONG*

In this scientific age of automobiles, airplanes, radios, radar, atom bombs, antibiotics, and so on, much of our progress has been due to advances in chemistry. Although it would be rewarding to review many of the contributions that chemical research has made for better architecture, this article will be limited to progress in the paint field. For discussion purposes, let us divide this subject into exterior and interior paints, and then analyze these on the basis of exterior surfaces (wood, masonry, and metal); and interior surfaces (plaster, composition boards, wood trim, and floors). Although this text will be confined largely to new construction, considerations affecting future maintenance will not be disregarded. In this connection, the writer suggests that the cost of painting, which is now one of the greatest, if not the greatest of all maintenance expenses, should be considered in terms of cost per square foot *per year*.

exterior wood

Some architectural firms prepare exacting specifications for most conditions, and yet fail even to suggest that the first coat of paint applied to wood siding or trim should be a foundation coat *designed* as a foundation coat. Although serious consequences are at stake, many specifications simply require two coats of X brand, or equal, for exterior paints. A specification prepared more intelligently will insist upon a first coat, designed as a foundation coat, and a second or finish coat, designed as a rain and sun coat. The longevity of these two coats and types of paint, which act together as a system, should be backed by attested performances observed on a large number of actual houses, for at least four years. A property owner is entitled to this length of service-life before a new finish coat need be applied. Although this length of service is quite attainable—even under extreme conditions—it cannot be obtained by specifying just any type or brand of paint.

There are two features of an undercoat or primer that help insure good performance over wood:

(1) A foundation coat should contain a substantial percentage (at least 30 percent) of thick linseed oil, heat-bodied until very thick. This ingredient controls the penetration of the paint vehicle so that the oil will be contained only within a few layers of wood cells at the surface. Illustrated are two cross-sections of wood to which different samples of paint have been applied. In one, the wood cells far below the surface are filled with oil (*Figure 1*). This penetration of oil, which has no advantage whatsoever, indicates that the film on the surface is uncontrolled and of indefinite composition. If it was considered that this paint had the correct composition when originally applied, it is apparent that such a condition no longer exists. In the accompanying illustration (*Figure 2*), the vehicle penetration has been limited to a layer near the surface by the thickened oil. A sound foundation has been provided so that uniform gloss and color will be permitted in the finish coat.

(2) A foundation coat should not contain zinc oxide. Zinc oxide is a base and like any base it reacts chemically with linseed oil to form zinc soaps that are somewhat soluble in water. When vapors from washing, bathing, and cooking emerge through the frame walls of a house, the soluble zinc soaps are dissolved and a paint failure is caused by the film being loosened at the interface. Although peeling will result from the water alone, the presence of soluble zinc compounds accentuates it. So, to avoid one cause of peeling, one should specify an undercoat containing *no* zinc oxide: cost will not be affected and the composition of the paint will be correct. The corresponding lead compounds are not as soluble in water, and will therefore cause less peeling. Either white lead or titanium in an undercoat is considered excellent.

In the finish coat, however, zinc oxide is not only permissible but desirable. The soluble zinc compounds act as detergents and help to clean soot from the exterior surfaces as the rains run over them. In the finish coat—a sun coat— the paint film consists of pigment particles surrounded by a vehicle. When sunlight (ultraviolet) beats down on the film, it destroys a very thin surface layer

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*Chemical Director, Devoe & Raynolds Company, Incorporated.

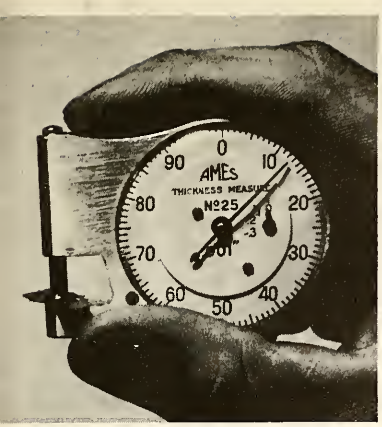

Figure 3—the thickness of a paint film can be quickly measured by a simple gage calibrated in mils. The micrometer shown above is manufactured by the B. C. Ames Company, Waltham, Mass.

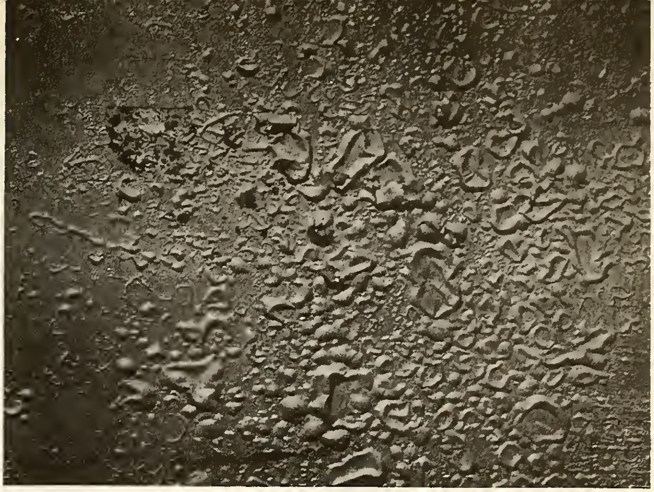

Figure 4—if water comes to a masonry surface at an excessively rapid rate, it will form paint blisters. In this illustration, some blisters have collapsed, cracks have appeared in others, and peeling has commenced.

of oil; the pigment, however, is not affected. After the oil in this layer has been destroyed, the pigment is loosened. One will recall that upon running a finger over such a surface the paint is rubbed off as chalk (actually titanium oxide). Later rains wash this chalk off of the exterior walls and down onto the ground. Subsequently, the ultraviolet light again destroys the oil in the next layer and thereby loosens more pigment. Succeeding rains wash these pigments away, layer by layer, through the film. This type of erosion is the proper way for a paint film to deteriorate and it will always leave the surface ready for new paint. Based upon such action it is apparent that the film thickness will determine the service-life in years. Paint specification requirements are rarely stated in terms of film thickness, and yet this is the surest method of all to guarantee the life of a paint job.

An undercoat and a finish coat should each have a thickness of two to two and a half mils; a total thickness for both coats should be from four to five mils. The actual thickness of a paint film is easily checked by means of a pocket-sized gage calibrated in mils (*Figure 3*). A job inspector can scrape off a small sample of the paint film and place it in the jaws of this micrometer; its thickness can be read quickly on the dial face.

one-coat house paint

Although unfamiliar to many, the one-coat house paint is one of the outstanding recent developments in the paint industry. The paint has been designed as a *finish* coat and should only be applied over an under-coating or over old paint. It has the following characteristics:

(1) Twice as much hiding power as any of the commonly specified paints. Most standard paints of the better American manufacturers have 18 hiding units per gallon. The one-coat paints not only have from 36 to 38 hiding units but also give a superior appearance to a paint job, both in uniformity and bright whiteness.

(2) Specially processed linseed oil, used as the vehicle, permits a painter to apply a film up to four mils thick in one application with an ordinary wrist-slap motion of the brush (as against two or two and a half mils for other paints). Further, this paint will not run or sag and will dry completely through. With this product, one can readily adapt film thickness to conditions of exposure. If a house is located north of the equator, its south side stands the severest exposure to the sun. It is wise to apply four mils of finish coat to the south side of a structure, but only two mils of finish coat to the north side. Two mils also will be satisfactory under eaves and porches; only one mil will be required to repaint these areas. Although this presents a new form of craftsmanship, it is in reality only a common-sense method—an element that up to now has been frequently lacking in painters' techniques, as well as in paint specifications.

metal

Like the principles outlined for wood surfaces, the first coat, that goes next to metal, should be designed to perform its specific job. In this case, one is not concerned with penetration, so the question of bodied oils does not arise. However, to stop rust or to inhibit rust already begun, the first coat on metal should contain one or more of the following rust-inhibitive pigments: red lead, blue lead, lead chromate, zinc chromate, zinc dust, or strontium chromate. Neither iron oxide nor aluminum flakes have rust inhibitive value. Although aluminum paint is not desirable as an undercoat on metal, it performs excellently as a finish coat or intermediate coat, as it offers more resistance to the passage of water than any other paint of the same film thickness.

paint screens

Screens of iron, steel, galvanized iron, copper, brass, and bronze should be painted to avoid unsightly stains which will otherwise occur under windows and screened porches. To eliminate screen staining, which is entirely unnecessary, one coat of zinc-dust paint should be specified. It is considered by far the best paint for this purpose; one coat will normally give adequate protection for about four years. This product is based on a standard formula which may be obtained from a number of manufacturers.

This kind of paint has other virtues as well, which deserve more recognition from architects. These significant characteristics are: it is rust inhibitive; it is about the only paint that consistently adheres to galvanized iron, copper, brass, etc.; and it is very durable as a finish or sun coat. One quart of zinc-dust paint will cover twelve half-screens. It also should be specified for exposed metal and stop drains. Although its color is gray, it can be tinted with other colors.

masonry

Three common sources of trouble are hot (alkaline), wet, and porous masonry surfaces. The old type of linseed-oil primer was easily saponified (burned) by the alkali in relatively fresh masonry surfaces. Resins are now available, however, which produce vehicles that are sufficiently resistant to alkali. Alkali resistance becomes secondary, or corollary to water. A primer should not be applied until the rate of water coming to the masonry surface is low enough so that it can diffuse through the thin paint film and escape to the air. If this rate is excessive, it will force blisters and bubbles and cause the paint to come off (*Figure 4*). Water will also bring fresh alkalis to the surface. When the rate of water coming to the surface is low enough to paint, one need no longer worry about the alkali. This has only been possible, however, since the advent of primers that contain relatively alkali-resistant resins.

Usually the period of waiting before masonry can be painted is a matter of weeks, not months. Among several of the factors affecting the length of this period are: wind velocity, temperature, rainfall, or humidity, and ventilation of new, wet plaster on interior jobs. One of the simplest and best tests to determine whether or not a masonry surface is ready for paint is to touch the surface with the palm of the hand; if it feels relatively dry, paint a small patch (say three or four square feet) and examine after 48 to 72 hours. If there are no blisters, an approved primer designed as an undercoat may be applied to the entire building. If a surface is quite porous, mix sand with the primer (say five pounds per gallon of primer) and apply with a scrubbing brush or old stub brush.

Portland cement water paints require a specific amount of water to form the hard substance characteristic of reinforced concrete foundations, pavements, and so on. A thin film of this paint often loses its water in the sun before the cement has united chemically with the water. The resulting deposit is powdery, porous, weak, and can easily be scratched off. Consequently, life is often short and maintenance costs high. "Oil" paints, in general, have lower maintenance costs per square foot per year. Over the primer coat, an oil paint should be applied. A flat finish is preferable to a glossy one, as the former allows any remaining water to emerge without difficulty. The alkyd-resin vehicle is considered best for exterior use and is especially suitable for a flat-finish coat over masonry.

alkyds

Glycerin, soybean oil, and phthalic anhydride, when cooked together in proper proportions, combine to yield alkyd resins. The three great virtues of the alkyd resins are: it has greater toughness; it is the only vehicle that does not turn yellow in interior use; it resists ultraviolet light better than any of the other vehicles. Because of these desirable properties, the alkyd vehicle has been used on every white refrigerator, every automobile, and nearly all buses, trucks, ships, railroad equipment, and agricultural equipment. This same type of paint vehicle is available in floor and deck enamels; trim and shutter paints; semi-gloss and gloss wall paints; trim enamels —flat, semi-gloss, and gloss; stains; and many other types of paint. Because of its superiority as a top-quality vehicle, it is recommended that architects specify that the foregoing classes of paints and enamel products be based on the alkyd vehicle. A more accurate name for this vehicle is glycerol phthalate; some states—Virginia, for example—require that this longer name appear on the paint-can labels. It is a generic name and is not limited to any one manufacturer. Although the cost of paints containing alkyd resins is about the same as that of other paints, superior results are obtained.

interior plaster

Method of application: over seasoned plaster, apply one coat of really alkali-resistant sealer and finish coat of flat paint; if cost permits a three-coat job, the second coat should be a blend of half-primer and half-flat.

A word about wall primer-sealer. In the past when such anemic colors as cream, ivory, gray, tenement tan, etc., were popular, it was not apparent that "so-called" sealers did not perform their assigned function. For a long time, the paint manufacturing industry was culpable for having sold millions of gallons of sealers that did not really seal. As light colors were usually applied over them, they seemed uniform and did not show color variations on the surface. As the public taste turned to deep tones, the inefficiency of these sealers became more apparent. Microscopic views of surfaces treated with these sealers usually looked like cobbled streets; sealed areas had roadways between them where the sealer had not penetrated the wall. When flat paint was applied over such a surface, it penetrated the roadways, leaving streaks, mottling, ghosting, and uneven color effects, especially in the popular dark greens, blues, and Burgundies. Extra coats also failed to give uniform color. The solution for this problem is to provide a sealer that truly seals. If a color scheme calls for deep tones, the architect must be assured that he specifies an efficient sealer—not all, even today, can claim this distinction. Several of the recently developed sealers containing alkyd vehicles have proven to be successful. The older types are very questionable, and although some architects still specify them, they will not succeed under deep tones.

composition board

This material is becoming widely used in place of wet plaster. Over taped joints, where smooth finish is desired, one coat of a so-called "rubber-emulsion" (synthetic) paint will serve well as a primer and also "lay" the nap or fuzz raised by sanding over the taped joint. Oil-base primers do not lay this nap down as well. Over the primed surface, the orthodox "oil base" or alkyd resin flats can be applied as usual in any color, pastel or deep tones.

the future

The chemist now synthesizes vehicles that have been produced on a basis of predetermined design. He makes atom models and studies them, just as an architect studies a blueprint. Many a paint product never gets beyond the atom-model stage; if it is considered faulty at this point, the laboratory does not attempt to create it. These facts are mentioned only to emphasize that paint is now designed on a scientific basis, and that accidental discoveries are few. If the architect allows himself to be guided by science, and not by color-card statements, the paints he specifies will have more lasting value for his client.

Wood Preservatives and Preservative Treatment

BY GEORGE M. HUNT*

What is the best wood preservative? No doubt this question has been asked thousands of times. The simple fact is that there is no answer, because there is no "best" wood preservative. Some preservatives excel for one purpose and others for other purposes. Nor is there any "best" method of applying wood preservatives. Pressure treatment is best under some conditions, and brushing, dipping, soaking, the hot-and-cold bath, or some other treatment may be preferable and more economical under other conditions. In fact, there are circumstances under which one may be justified in using no treatment at all.

Where do these facts leave the architect or home owner who needs to make a choice with regard to the use of treated wood? Should he accept the recommendations of the first salesman who calls or the first advertisement on the subject that comes to his attention? If he followed that procedure, he would be right sometimes but wrong probably more often. His only alternative is to seek the advice of a qualified, unbiased consultant or learn for himself how to make an intelligent choice. There are so many factors to be considered that it is not easy to lay down simple rules for making a choice.

In outdoor structures, such as bridges, railway tracks, pole lines, and the like, oils like coal-tar creosote or creosote mixtures, or heavy oil solutions of toxic chemicals applied by pressure methods are generally preferred. Railway men, highway engineers, public utility engineers, and others concerned with such structures are either sufficiently well informed to make their own decisions for their structures or they know where dependable advice can be obtained. There is one "best" in this connection that may be mentioned, however. For the protection of piles and timbers that will be in salt water, only coal-tar creosote or creosote-coal-tar mixtures should be used. They should be applied by a full-cell pressure process and the wood should be made to absorb all the preservative it will hold. No other preservative is dependable for this job and it is a tough one for creosote.

For homes and small buildings in general, creosote and similar preservatives may be, and frequently have been, used with good results. Their color, odor, and oily nature, however, make them unattractive for this purpose. Workmen do not like to build with creosoted lumber. The creosote gets on their clothes, it has a strong odor and, occasionally, untreated flooring has been discolored when laid over creosoted subflooring or nailing strips. For these reasons, wood treated with creosote will never enjoy as much popularity for buildings as the so-called "clean" preservatives.

Clean preservatives are of two types, depending on whether the toxic chemical is dissolved in water or in a volatile, organic solvent. Chromated zinc chloride, Chemonite, Celcure, Greensalt or Erdalith, Tanalith (Wolman salt), and a number of others are of the water-borne type. They are usually but not necessarily applied by pressure methods. They have the disadvantage of making the treated wood very wet and swollen. Wood treated with water-borne preservatives must, therefore, be redried before it is used in buildings, in order to avoid the shrinkage and loosening of joints that result when wood is installed wet and allowed to dry in place.

Clean preservatives of the organic-solvent type usually consist essentially of a solution of pentachlorophenol or copper naphthenate in a petroleum solvent, such as kerosene, Stoddard solvent, or light domestic fuel oil. Other toxic chemicals are sometimes used or added to the pentachlorophenol, as well as other oils or waxes to provide water repellency, prevent surface crystallization or increase solubility. An outstanding characteristic of these preservatives is that they do not swell the wood. The freshly treated wood must be dried sufficiently, however, to permit the solvent to evaporate and to get a clean, dry surface, especially if the wood is to be painted. Immediately after the treatment, the wood is highly inflammable because of the oily solvent on the surface but this condition gradually changes as the solvent evaporates.

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* *Former Director, U.S. Forest Products Laboratory, Madison, Wisconsin.*

Left—fungus and incipient decay on this window sash could probably have been avoided by using the standard National Woodwork Manufacturers' Association three-minute dip treatment. ***Photos: except as noted, courtesy of Bureau of Plant Industry, Soils, and Agricultural Engineering.***

Frequently, waxes or other suitable materials are added to the clean, organic-solvent preservatives to increase their effectiveness in retarding moisture changes, thus providing nonswelling, water-repellent preservatives. There are numerous proprietary preservatives of this type, most of which contain five percent of pentachlorophenol in the ready-to-use mixture. They do not actually moistureproof the wood but, when properly applied, they slow down the rate at which moisture changes can take place and measurably retard shrinking and swelling of the wood under fluctuating moisture conditions. There is some indication that the presence of the water repellent also adds to the effectiveness against fungi.

All the preservatives named above, and numerous others, are good preservatives and will provide protection from fungi or insects, if they are present in the wood in sufficient quantity and depth. They vary in cost, of course, and in the amount required for a given degree of protection. Of outstanding importance is the fact that no preservative can be depended upon for good results when improperly used. Fungi and insects are methodical and thorough in their search for unprotected wood because their lives depend on finding it. When conditions for their growth are otherwise favorable, they will ultimately discover the weak spots in any treatment resulting from shallow penetration or checks extending through the treated zone. In preservative advertising and in general discussion of the subject, too much attention is given to comparing preservatives and too little to the importance of good treatment.

When using any preservative, the highest degree of protection is obtained when the largest possible amount of preservative is injected into the wood to the greatest possible depth. Such treatment should be specified when creosoting wood piles for use in salt water, but it is not necessary or economical in preservative treatments for buildings. For the preservatives in commercial use by pressure methods, standard specifications state the minimum amount of preservative required per cubic foot of wood treated. Experience has shown that when the wood is well penetrated and contains not less than the specified amount of preservative, good protection may be expected. Larger quantities and deeper penetrations give greater assurance of long life but may be unnecessarily costly for most purposes.

Pressure treatments generally afford the best means of securing the desired penetration and absorption of preservative because the treating-plant operator can vary the treating temperatures and pressures and apply steam, air pressure, or vacuum as needed for the preservative used and the material being treated. It is sometimes possible by certain nonpressure methods to secure as deep penetration as by pressure methods and, when this is done, the protection obtained will be as great as by pressure treatment. Such deep penetrations by nonpressure methods, however, usually require higher preservative absorptions than specified. This makes for longer life but, also for higher cost of treatment.

Where large quantities of lumber are involved in a single order, pressure treatment is the preferred practice. It is also desirable for small quantities when they can be obtained at reasonable cost. In some cities retail lumber yards or jobbers are able to supply pressure-treated lumber in relatively small amounts. When it is not thus readily available, the prospective user seldom can afford to have a special order treated for him since, with few exceptions, pressure-treating plants are not equipped to handle small orders at reasonable cost. He may, however, choose one of the numerous nonpressure treatments, the choice being influenced by the kind and quantity of material to be treated, the availability of suitable treating facilities or treated lumber, and the degree of protection desired.

The simplest and cheapest treatment is to brush or spray the preservative on the wood. Unfortunately, it is also the least effective method, for the simple reason that the amount of preservative absorbed by the wood is low and the penetration is usually slight, frequently not more than one thirty-second of an inch. The quantity absorbed can be increased somewhat by repeated applications but not much improvement in penetration will result. Such superficial treatments, particularly if the treated wood is painted subsequently, will have a retarding effect on fungi and insects but they cannot safely be depended upon for long life. The treated surface is easily broken or worn through and, if checks develop, they will penetrate through the treated area and provide access to the untreated wood beneath. Paint, of itself, provides little or no protection from decay, but where applied over a treated surface, helps to reduce wear and checking and tends to prolong the effectiveness of the preservative on the surface. Surface treatments should be used only as a last resort, when no better method of retarding decay is practicable.

Immersing the wood in a tank of preservative is almost as simple as brush application but costs more because more preservative is absorbed, more equipment is required, and a substantial amount of preservative is needed to fill the tank. Because of this higher absorption and generally deeper penetration, greater protection can be expected than from brush treatment. When the wood is immersed for only a few minutes or less, the treatment is referred to as dipping. When the immersion period is in an oil solution for several hours or days, it is often called "cold soaking."

In these treatments it is customary to use clean, nonswelling preservatives, such as solutions of pentachlorrophenol in Stoddard solvent or kerosene. Copper naphthenate solutions may be used instead of pentachlorophenol when the green color of the copper naphthenate is not objectionable. For the most part, dipping treatments are for "home" or "on the job" use. One important commercial application that has developed, however, is the three-minute dip treatment for window sash, frames, and other millwork sponsored by the National Woodwork Manufacturers' Association. The finished sash or frames

Right—preservative treatment would have prolonged the life of this window sash; it rotted because of moisture accumulation.

are immersed by the manufacturer or dealer for three minutes in a standard preservative solution containing not less than five percent of pentachlorophenol or its equivalent. The cost of the treatment is slight and it is good practice to require it for homes and similar structures. While the penetration into the sides of the sash members is usually rather limited, good absorption and penetration are common in the end surfaces and joints in sash made of ponderosa pine or other easily treated wood. These are also usually the points first attacked by stain or decay fungi. In structures where conditions are usually favorable to decay, the three-minute dip treatment will give limited protection but more thorough impregnation is needed for maximum effectiveness.

Cold-soaking is more often used for fence posts and outdoor structures than for house lumber, but it can be used for that purpose. With dry, easily treated material like the sapwood of pine lumber, fair absorptions and penetrations can be obtained by soaking it two or three days in pentachlorophenol or copper naphthenate solution. The effectiveness should be correspondingly better than for dip treatments. Such long treatments would not do for window sash and frames because many of them would absorb too much preservative and would require months of drying after treatment to remove all danger that the preservative would discolor paint, plaster, or woodwork in contact with the treated wood. For lumber not exposed to view in the completed structure, and not in contact with plaster, no such result need be feared. Furthermore, the lumber commonly used for the concealed parts of houses is usually less absorptive than the pine used in window sash, and much less likely to absorb excessive amounts of preservative.

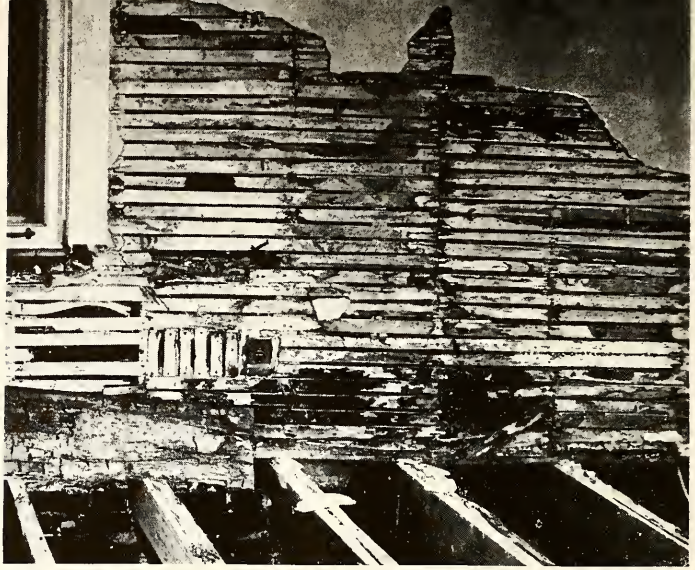
Water-borne preservatives may also be applied by soaking the wood in them for several days or weeks at ordinary temperatures or with some heat. Such treatment is usually referred to as steeping. It gives limited absorption and penetration and is not often used for house lumber. Because of the water absorbed during treatment, the treated wood should be thoroughly dried before use. An advantage of steeping wood in water solutions is that it may be applied to lumber in any stage of seasoning, from thoroughly green to thoroughly dry, while cold-soaking with oil solutions requires dry lumber. The steeping method finds very little use in this country for either commercial or "home" treatments and seldom can be used to good advantage for treating house lumber.

Hot-and-cold bath treatment consists in heating the wood in an open tank of preservative and then immersing the hot wood in cold preservative, or allowing the hot wood and preservative to cool together. The method finds commercial use for poles and posts but is not commonly used for house lumber. It is used mainly with creosote and similar oils that can stand heating without much loss by evaporation, and these preservatives are not popular for house lumber. Water solutions can be used, however, if sufficient care is taken to maintain the right solution concentration and treating temperatures. Light oil solutions are too volatile and inflammable to heat safely in open tanks but may be used by subjecting the wood to a vacuum in a closed tank and then admitting unheated light oil solution without admitting air. A few small commercial installations at millwork plants treat millwork products by this method. With water solutions, a similar effect may be produced by heating the wood with steam in a covered or closed tank and then covering it quickly with cold preservative.

Many other methods of treatment could be described, but the foregoing are the principal ones likely to be proposed by those selling treated wood or preservatives. A long list of preservatives could also be described and compared, but differences in the effectiveness of preservatives of recognized standing are generally much less important than the thoroughness with which they are applied, and such characteristics as color, odor, cleanness, and swelling properties. One should beware of accepting a preservative of unknown composition or one for which extravagant claims are made, but any preservative in good standing will give good protection when properly used.

One of the most practical means of avoiding decay and insect damage in houses and similar buildings is to design and construct them in such a way as to avoid the conditions that favor such deterioration. Keeping the wood in the structure dry at all times is the principal precaution to observe. Any condition of design, construction, or use that favors the accumulation of moisture in the wood favors decay. Condensation of water on windows, walls, or attics should be avoided. Placing wood in contact with the soil or damp concrete favors decay and, in regions where termites are active, favors their attack. Lack of ventilation in crawl spaces under basement-

Right—expect this to happen whenever untreated wood is placed in contact with the ground, a concrete porch or sidewalk, or any other good source of moisture. *Photo: courtesy of Forest Products Laboratory.*



Right—dampness from an unventilated crawl space resulted in rapid decay of the wood in this house in Florida. It is wiser to avoid such conditions than to depend on preservative treatment to protect the structure from their consequences.

less houses encourages decay fungi and termites. It is much better to avoid such conditions than to depend on preservative treatment to protect the structure from their consequences. There are numerous publications that discuss these conditions and tell how to avoid them but far too frequently their recommendations are ignored. Can it be because too many architects and builders concern themselves only with the appearance of the new structure and pay little or no attention to the factors of durability and low maintenance costs? Some architects, at least, have thoroughly informed themselves on the details of preventing fungus and insect damage and do a consistently good job in protecting their clients.

The heartwood of naturally durable species such as cedar, cypress, and redwood is, of course, resistant to decay and suitable for use in places of moderate decay hazard. The availability of all-heart material is becoming less each year, however, except in a few favored places. Sapwood or mixed heart and sapwood is not resistant to decay.

When it is known that conditions will favor deterioration despite the best that can be done in the way of design and construction and when wood of satisfactory, natural durability is not available, treated wood should be used. A preservative in good standing should be employed and applied to the wood by the most thorough method that it is practicable to use under the prevailing conditions. Furthermore, the treated wood should not be cut into or trimmed any more than is absolutely necessary, because cutting exposes untreated wood beneath the treated surface and provides open gateways for the entrance of fungi and insects. Best practice requires that the wood be cut to finished dimensions before treatment. When that is impracticable, all cut surfaces should be coated liberally with preservative.

Most preservatives in the amounts used for decay prevention do not significantly increase the fire resistance of wood. This would not be expected of preservative oils but even with water-borne chemicals, the amounts that remain in the wood after drying are generally too small to have much effect. For preventing decay, the net retentions of dry chemical in the treated wood are usually only fractions of pounds per cubic foot of wood but, for substantial fire retardance, several pounds per cubic foot are needed. Furthermore, only a few chemicals that have preservative value also are effective fire retardants. Among these are borax, boric acid, and zinc chloride. To these it is customary to add a large proportion of ammonium phosphate or ammonium sulfate in preparing fire-retarding solutions. For best results these are injected into the wood by pressure methods in amounts that will leave three to five pounds of the dry mixture per cubic foot of wood. The high cost of such treatment puts it out of reach for the frames and woodwork of homes of low or moderate cost. Fire-retarding treatment is used industrially to the extent of several million board feet per year, however, and a number of commercial treating plants are prepared to furnish fire-retardant treated lumber, interior trim, flooring, doors, or other products.

Fire-retarding paints are available that can be applied by brush or spray and will give a considerable degree of protection against ignition or spread of flames from small fires. Some of these are proprietary products of high effectiveness and formulas for others are available.

The use of wood treated with fire-retardant chemicals or paints has only a limited effect on the fire safety of a house because treating the wood does not protect the contents of the room or building. Fire can spread rapidly through the inflammable contents of a room even in a house made of concrete. The wood itself, however, is greatly benefited by fire-retardant treatment in that it serves to retard rather than feed the flames that may come in contact with it.

In this brief summary, it is not practical to discuss the many details relating to the selection of preservatives, fire retardants, and treating methods. The U. S. Forest Products Laboratory at Madison, Wisconsin, has numerous publications on these subjects that may be obtained without cost. Information is also available from other branches of the Department of Agriculture and from a number of state forest schools and laboratories, as well as from industrial concerns and associations. In making inquiry of any of these sources, the inquirer should be specific in stating the questions he needs answered.

Research Report: Surface Waterproofing with Silicone Resins

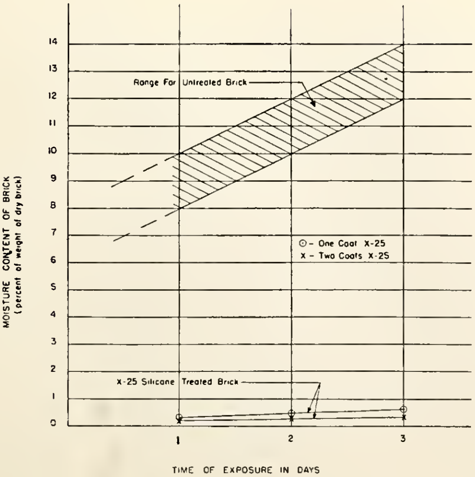
BY F. O. ANDEREGG*

It is unfortunate, but true, that many buildings with masonry walls are found to leak when subjected to rainstorms. In some cases, especially in winter, an unsightly efflorescence may demonstrate that moisture is penetrating the masonry. To remedy these conditions, the application of surface waterproofing would seem to be the logical procedure. However, a careful study should be made of each job to find out where the moisture enters, whether directly into the wall from exterior leaks above grade, or from condensation of water vapor entering the inner surface of the wall. Moreover, the advantages and limitations of the various surface waterproofers should be known. Since they are subject to a variety of exposure hazards, their reactions to a given severity of attack must be understood before an adequate waterproofing job can be undertaken. As with most problems, when a thorough study is made, a variety of factors are encountered which are not always evident on first examination.

background

The problem of surface waterproofers has been studied for more than a quarter of a century. It began at Purdue University in 1924 with the study of Efflorescence and Staining of Indiana Limestone,"[1] and was continued at Mellon Institute on the subject of "Water-tight Brick Masonry."[2] Recently, the study has been brought up to date by a variety of research and consulting jobs which culminated with two papers on surface waterproofers from the John B. Pierce Foundation.[3, 4]

Figure 1—moisture absorption of bare and X-25 silicone treated brick.



The wax and aluminum stearate colorless waterproofers available at the time were studied. They have been kept under continuous observation over the intervening years, and their limitations have been reasonably well defined. This field experience has allowed a compilation of these limitations which include:

Factor 1: *Some change in appearance of the masonry* due to thick coatings over sharp corners which diffract the light.

Factor 2: *Incomplete exclusion of moisture.* Since the bulk of the surface waterproofer is solvent, the larger pores still are not closed after solvent evaporation even though they are reduced in size and possess some water repellency.

Factor 3: If the masonry texture is sufficiently fine, that is, if the pores are small enough so that a continuous film could be produced by the waterproofer, *the "breathing" of the wall is interfered with.* This causes the accumulation of blisters behind the coating, due to osmotic pressure and vapor pressure lowering, which tend to detach the film bodily.

Factor 4: *The life of the surface waterproofer is short.* This appears to be caused by: a) differential volume changes aided by preferential wetting are effective in detaching these surface coatings, and b) oxidation which may cause embrittlement and more ready detachment of the film.

Factor 5: Finally, where soluble salts are present in masonry, penetrating moisture dissolves them. This moisture can come to the surface, evaporate, and deposit salts directly behind the surface coating. The salt crystals grow with changes in temperature and moisture conditions in oriented directions and exert tremendous forces. *The surface coating may thus be pushed off bodily.* This phenomenom, although not generally appreciated, causes millions of dollars' worth of damage to our masonry structures every year. The salts may be in the stone, brick or concrete masonry units, in Portland cement or sand used for mortar, or may be formed from the sulphuric acid found especially in winter rains which enter the wall.

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* *Consulting Specialist on Building Materials.*

Based on this experience and analysis, a set of test methods has been developed[3] and applied to a variety of surface waterproofers. The results of these tests seem to compare well with actual service conditions, so that they predict the performance of any surface waterproofers tested. They determine the water penetration through the waterproofing film under controlled conditions; the transpiration or "breathing" rate; resistance to forced efflorescence from within; and finally, the resistance to weathering, both in the presence and absence of the soluble salt, sodium sulphate.

silicone resin waterproofing, general

The most interesting and promising materials recently studied for surface proofers are a series of silicone resins. They are applied by flooding the surface with a dilute solution which seems to provide the masonry pores with the diffraction of light (Factor 1). Within reasonable limits of pore size, the treatment is quite effective in excluding liquid water (Factor 2). Pores finer than about 1/32" which are treated seem to be able to exclude water under a head of 1/4". This is approximately the pressure exerted by a 20-mile-per-hour wind. For large cracks and fissures, tuck pointing or grouting appears a necessary prerequisite. The pores have not become appreciably clogged by the treatment, so that the rate of transpiration or "breathing" is essentially that of an untreated wall (Factor 3). Silicones may be affected by Factor 4, although where silicate masonry materials are involved, hydrolysis of the silicone halides may result in direct attachment to the masonry surface by primary or secondary valence forces. Certainly the excellent resistance of silicones to oxidation under varying conditions of humidity is well known, making this a factor of importance. Under very severe exposure on the roof, some loss in ability of the silicone waterproofing to exclude water was noted after two years. This reduction may be expected to vary with the severity of exposure. Where not too severe, an effective life of 8 to 10 years may be reasonably predicted. When soluble salts are present in quantity, trouble is to be anticipated (Factor 5). The application of silicone waterproofing to very old walls, showing signs of efflorescence disintegration, should be made with caution. However, on bricks tested in the laboratory by forced efflorescence, definite progress was made toward remedying this problem.

specific test data

Using test methods which had been developed previously, a series of tests have been run with certain silicone resin solutions supplied by Linde Air products, Division of Union Carbide and Carbon Corporation. Ten masonry units were run in each experiment. Units which were not bricks were cut to approximate brick size. One flat side and the four edges were coated by flooding with the resin solution. After allowing a short time for solvent evaporation, the treated flat surface was placed in contact with water maintained at a level of exactly 1/4 inch, which approximates the pressure exerted by a rainstorm with a wind of 20 miles per hour. The units were weighed after 24, 48, and 72 hours and their moisture pickup compared with that of ten similar units.

The silicone treated bricks were then loaded with moisture through their untreated sides until they contained approximately as much moisture as an untreated brick after three days' exposure. They were then placed, untreated side down, on a rubber sheet which tended to seal off the untreated side and to allow evaporation of moisture through the silicone film. Weighings were made at intervals to note the rate of transpir-

Table I: Waterproofing of Masonry Units with "Linde" Silicones

Silicone No.	*Masonry Unit*	*Coats of Waterproofing*	*Per cent Water Absorption in*			*"Breathing"*	*Resistance to Forced Efflorescence*
			24 hr.	48 hr.	72 hr.		
X-25	Shale Bricks	None	8-10	10-12	12-14	Very good	Poor
		One	0.3	0.5	0.7	Very good	Excellent
		Two	0.27	0.30	0.32	Very good	Excellent
X-25	Waylite Concrete	None	3.4	3.8	4.4	Good	Fair
		Two	0.69	0.85	1.2	Good	Good
X-25	Sand-Lime Bricks	None	13.2	13.7	14.3	Very good	Excellent
		One	7.1	—	—	Good	Excellent
		Two	6.0	—	—	Good	Excellent
X-25	Ohio Sandstone	None	6.3	6.3	6.8	Good	Poor
		One	1.1	1.4	1.5	Good	Poor
		Two	0.6	0.8	0.9	Good	Fair
X-25	Indiana Limestone	None	4.2	4.2	4.2	Good	Poor
		One	3.7	3.8	3.9	Good	Poor
		Two	3.7	3.9	3.9	Good	Fair

ation or "breathing."

The next test consisted in placing the untreated sides of five of each set of units in contact with a ten percent solution of sodium sulphate for one week to see whether migration of the solution to the surface would result in the deposit of any efflorescent salts. The results of these tests are given in Table I and are shown graphically in Figures 1 and 2.

conclusions

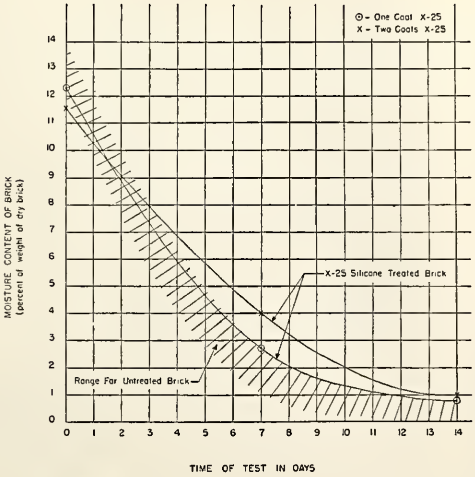
The results of these tests are most interesting. They indicate that the silicone waterproofer has overcome most of the limitations of earlier materials. The effect of the coating on color tone and appearance was negligible. For most of the masonry units tested, water absorption was reduced to a minimum, although the silicones seem to be more effective on siliceous than on calcareous units. While two coats had a somewhat more effective waterproofing effect on bricks in this test than had single flooded-on coatings, the extra benefit would hardly seem to justify the extra cost. Figure 2 indicates that the coating permits effective transpiration of any moisture which enters the bricks from inside surfaces. While results of the forced efflorescence test were mixed, the excellent results on shale bricks, which are normally quite prone to forced efflorescence, seem to show that eventually the silicones can be made to perform well here.

By these tests, the silicones have been found as new and improved surface waterproofers. Their continued and expanding use on actual field problems is indicated, and will ultimately prove the range of their applicability to the problems of masonry waterproofing and preservation. Meanwhile, they continue to be promising new materials for study and testing on the many waterproofing problems which continually confront the architect, builder, client, and the building maintenance man.

references:

1. "Efflorescence and Staining on Indiana Limestone," Purdue University Experiment Station, Bulletin 33 (1928). Anderegg, Peffer, Judy and Haber.
2. "Water-tight Brick Masonry." F. O. Anderegg. *Architectural Record,* August 1931.
3. "Testing Surface Waterproofers." F. O. Anderegg. A. S. T. M. Bulletin, January 1949.
4. "Results on Testing Surface Waterproofers." F. O. Anderegg. A. S. T. M. Bulletin, January 1951.

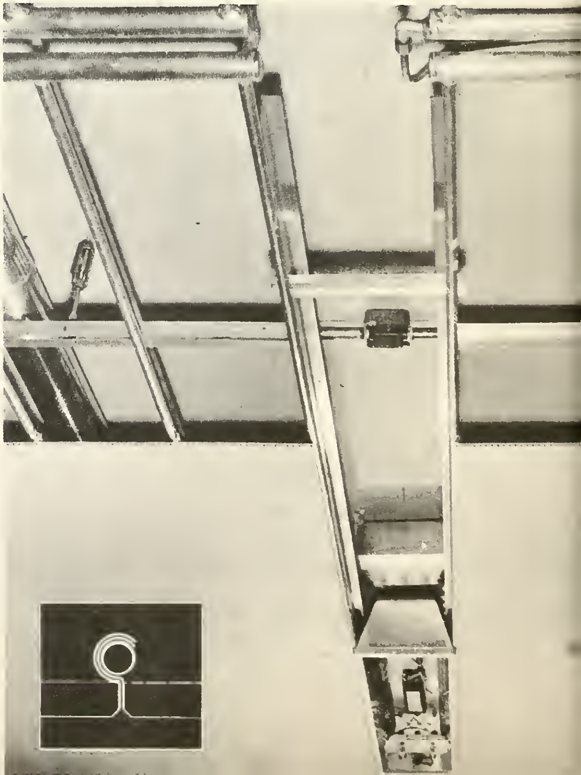
Figure 2—moisture transpiration of bare and X-25 silicone treated brick.



ENVIRONMENT CONTROL—

Since World War II, developments in heating and cooling have been as active and numerous as in any other phase of contemporary architectural-engineering design. Most of the "new" refinements have exploited the radiant phenomena that heat migrates from the warmer surface to the cooler surface and that in a radiant system sensation of comfort may be obtained within a considerably wider range of temperatures. Both water and air are used successfully as the heating medium—hot-water radiant heating has become standard in many speculative housing developments just as there are countless warm-air radiant heating systems in similar projects. The most recent advances, however, have been in the field of radiant cooling. For a long time (up to 1950) whenever one inquired about radiant cooling, he was always referred to Charles Leopold, Philadelphia Consulting Engineer, as "the only man who really knows much about it." Since that time, however, many other mechanical engineers have also become experts in this field and the largest installation to date is found in the Aluminum Company of America Building, Pittsburgh (*page 40*). This installation designed by Jaros, Baum & Bolles uses a perforated, aluminum-panel ceiling for both radiant heating and cooling on all 30 floors. An interesting supplementary use of radiant-cooling ceiling panels has

Concrete double roof at Kano, Nigeria (above) *and spray system on roof in Austin, Texas* (below).

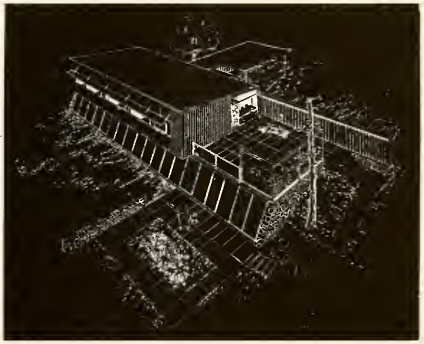


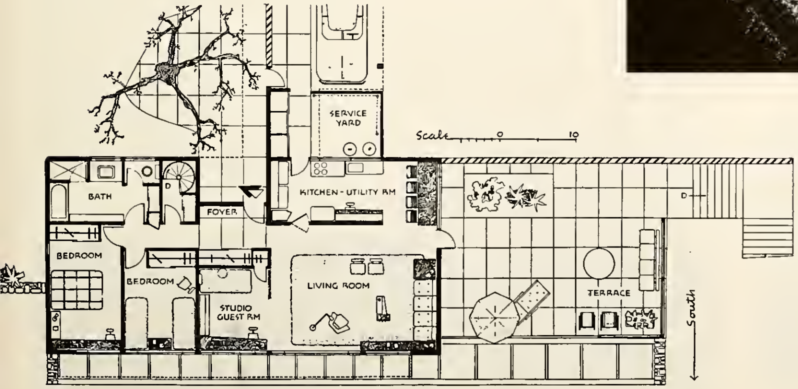
just been installed in the Port of New York Authority Building, New York. On one of the upper floors radiant cooling panels were installed at the periphery of the critical exposures to reduce the load on the air-conditioning equipment. John B. Dillon & Associates and Richard Geomann have successful air-panel cooling systems in operation in the New York area. These systems have employed both cellular-steel floor panels and aluminum cooling ducts (in ceiling) interlocked with acoustical panels to carry the cool air (*page 283*).

At M.I.T. exhaustive studies have been made in order to determine how best to harness solar energy, which is free, so that it will serve as an economical and efficient means for heating the residence. Although these studies have progressed far and are quite workable, they must still be considered experimental. Problems of orientation have long been solved, yet there are developments and improvements still to come in the collector and storage systems before we can consider the solar house for large scale use. In "Design Procedure for a Solar House," George S. Sharon brings the reader up to date on present day concepts for solar heating (*page 269*).

We are presently moving toward year round air conditioning for all types of

Radiant heating-cooling panels in the Alcoa Building, Pittsburgh, are clipped to aluminum tubes by means of integral, continuous-type grips (acrosspage). *Design for solar house* (below and right).

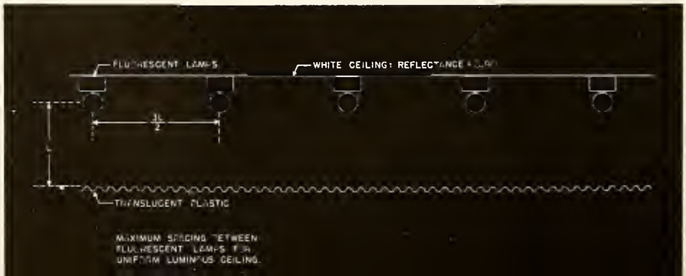




occupancies, and manufacturers of this kind of equipment are predicting that within five years residential air conditioning may be considered in the same category as automobiles and refrigerators. There is hardly an office building being erected today that does not incorporate full air conditioning and an increasing number of existing structures are deriving the benefits of individual, unit air conditioners and "shoe-horned in" central systems. In the face of such a titanic and growing industry, it is almost heresy to mention it but—if one listens carefully he cannot help but hear an occasional, almost unbelievable sentiment from some corners that summer air conditioning, as we now know it, is still not the answer. For this reason and because the operation of air-conditioning equipment is occasionally interrupted, the wise designer does not specify that all windows be fixed and allows some means to take advantage of natural ventilation. When planning for present and future residential air conditioning be sure to consider the articles by William J. McGuinness (*page 284*) and Robert H. Emerick (*page 290*). In anticipation of future methods for keeping ourselves comfortable in winter and summer, one would do well to keep in touch with current developments in reflective conditioning as presently pioneered by Dr. Clarence A. Mills of Cincinnati.

In the field of lighting one cannot help but be impressed with the growth of luminous ceiling installations. Although it was found that ordinary white tissue paper was the best diffusing medium, its obvious limitations have made thin sheets of corrugated acrylic and vinyl plastic the next best choice of material, from a practical point of view. Luminous ceilings most frequently combine the diffusing medium with incandescent and/or fluorescent lamps. In the evolution of light sources—from *point* to *line* to *area*—we must watch with interest the developments that may come from Sylvania Electric Products, Inc. They have already developed a genuine area lighting source consisting of a special sheet of conductive glass on which is placed a phosphor-dielectric coating and a layer of vaporized aluminum. Although now in its infancy, this electro-luminescent lamp, really a sandwich of light, should someday take its place as a major light source. Presently, the commercial availability of the lamp is limited to: (1) a green luminosity of 0.1 footlambert when connected to a standard 120-volt, 60-cycle circuit; (2) a green luminosity of not over 2.0 footlamberts when a 500-volt step-up transformer is made part of the circuit.

Recommended lamp spacing for a uniform luminous ceiling (below). *Major indoor light source of future may be sandwich of light—the electro-luminscent lamp* (left).



Comfort Factors Affecting Heating Design

BY ROBERT H. EMERICK*

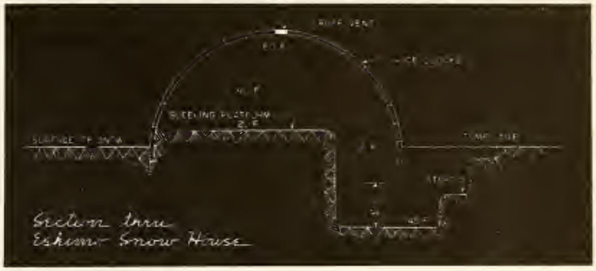


Figure 1

comfort factors in winter

The most fallacious evidence of heating comfort being accepted today by the American people, is a reading of 70F on a room thermometer five feet above the floor.

Actually, this concept of 70F indoors and 0°F outdoors, serves most usefully as a standard temperature difference against which to measure the heat output of any given unit of heating equipment, such as a radiator, convector, or bare pipe. But, if we attempt to use it as an indicator of comfort, we shall experience unsatisfactory results for the following reasons, tradition to the contrary:

First, studies made in test houses, notably by the National Bureau of Standards, disclose that temperature variations between the floor and ceiling of any given room, range from 10 to 20 degrees, depending on the heating system employed. Obviously then, a temperature taken five feet above the floor, the so-called "comfort line," cannot really be indicative of a comfortable temperature in the room. It must be remembered that the crown of the average human head, when its owner is seated, is not five feet above the floor, but approximately four feet and five inches. Consequently, much of the body finds itself in an atmosphere appreciably cooler than 70F—particularly the feet, in their toe-less, heel-less, and almost upper-less shoes of current custom, which are obliged to exist shiveringly in an atmosphere of perhaps 65F, or cooler.

Second, the very figure of 70F as a desirable ambient, is not accepted everywhere with uniform enthusiasm. According to Stefansson's Artic Manual, temperatures inside the Eskimo's snow house *(see Figure 1 for cross section)* will range from 0°F to 60F, during periods of –50F outdoors. The high value exists only in the extreme dome. The important fact, here, is that Eskimos strive to maintain low temperatures beneath their icy roofs and any sign of melting is immediately countered by hacking the walls to a greater thinness.

On the other hand, these same Eskimos in their permanent wood homes appreciate an ambient of 90F or more, and customarily strip to the waist to obtain comfort. Obviously, 70F to these people is merely a way station passed when going from one degree of comfort to another.

Lest the Eskimo is thought to represent an extreme, consider British custom. At Oxford University, comfort is thought to lie between 55F and 70F, with most of the 30 colleges (26 male and four female) preferring the lower values.

No doubt the English habit of wearing adequate winter clothing is a key factor in finding comfort at such low ambients; however, Americans desire to wear as little as possible all year 'round and we must design accordingly. This writer never designs for less than 74F, and if much zero or sub-zero weather is common, 76F to 78F is used, depending on the construction of the building.

These relatively high design temperatures are essentially due to the heat loss by radiation from the human body—particularly in a lightly clothed society such as our own. Normal skin temperatures may be expected to average these values:

Forehead and cheek	93F
Neck	94F
Hand (palm)	91F
Feet	80F

Heat is lost therefore, by radiation from our skin to every cooler surface it can "see" (the rays travel in straight lines) and the rate of loss can be computed by the Stefan-Boltzmann equation which states that the loss is proportional to the 4th powers of the absolute temperatures of the surfaces involved.

Mathematically, the equation looks this way:

$$q = 0.174e \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right]$$

q = Btu per hour per square foot.
0.174 = An experimentally determined constant.
e = A surface emissivity factor. For the purposes of this study, an assumed 0.9 will be satisfactory.
T_1 = Absolute temperature of the warmer body—in this case the human skin.
T_2 = Absolute temperature of the cooler surface—in this case the room walls, window glass, tables, or anything in direct line of view and having a temperature lower than the skin.

Since heat transferred by radiation has no effect on the intervening air, we can stand in a room apparently warm enough—the traditional 70F is a classic example—and shiver until our teeth rattle solely because the walls are so cold they are withdrawing heat from our bodies at an excessive rate. Some years ago this situation was called "cold 70," and because the reason was not commonly understood, many a heating contractor was accused of achieving his guarantees by means of fixed instruments.

There are two ways of solving the problem. First, we can wear more clothing, which is unthinkable, or we can provide an ambient temperature suffici-

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**Consulting Mechanical Engineer, North Charleston, South Carolina* ently high to counteract the losses from our bodies by radiation. As mentioned before, this ambient may be found nearer 80F, than 70F.

Figure 2, "Ambient Temperatures to Counteract Radiation Losses," offers a guide that may be helpful in designing to avoid "cold 70." Inside wall temperatures may be computed easily from the following formula:

$$\text{Wall temp., F} = R_t - \left[\frac{(R_t - O_t)k}{1.65}\right]$$

R_t = Room temperature, F
O_t = Outside temperature, F
k = Coefficient of heat transmission through wall. Available for different wall constructions in the A.S.H.V.E. Guide.
1.65 = A surface coefficient determined experimentally by the A.S.H.V.E.

As an example of this formula's functioning, suppose we have a brick veneer wall on frame backing, with a coefficient of 0.36, an inside temperature of 70F, and an outside temperature of 0°F. Multiplying the temperature difference of 70 degrees ($R_t - O_t$) by 0.36 which is the k factor, approximately 25 Btu will be transmitted through every square foot of that wall in one hour. Dividing these 25 by the inside surface coefficient of 1.65, we observe that approximately 15 degrees must be substracted from the inside temperature to arrive at the wall temperature, which figures to be 55F.

If we exercise the Stefan-Boltzmann equation for a wall temperature of 55F and an average skin temperature of say 82F, the radiation loss computes to approximately 25 Btu per hour per square foot of bodily surface. The total loss for the average human figure with an area of 15 square feet would therefore be 375 Btu per hour. Since the normal loss for a person seated and at rest is about 300 Btu per hour in an ambient atmosphere of 70F, the reason for our shivers at "cold 70" is quite obvious.

If there exists any doubt as to the proper height of the design temperature, it is prudent always to *select the highest considered.* There is nothing more irritating to the average urban American, than a feeling of cold discomfort.

comfort planning

We all know that complete comfort in a home requires, in addition to the proper temperature, considerable uniformity of temperature distribution, the establishment of satisfactory humidity, air treatment for the removal of pollens and dusts, the control of odors, the destruction of harmful viruses and bacteria, an understanding of correct furniture placement, suitable lighting, and the provision of color schemes expertly selected to meet the temperament and physical peculiarities of the occupants. Nervousness can produce a feeling of chill, particularly in the hands and feet, so can deep fatigue; every interior decorator is aware that colors may be warm, cold, or neutral, soothing or irritating, and as a result disagreements on whether a room is comfortable or not, can originate in these psychophysical reactions.

Comfort planning, therefore, requires the architect to coordinate with his own skill of design, the very special skills of the engineer, the lighting expert, and the interior decorator.

problems of temperature uniformity

This writer has been concerned again and again with architectural designs, particularly in the southern United States, which expose the underside of a house floor either directly or indirectly, to all the wintry winds that blow. The result inevitably is a cold and drafty floor that destroys uniformity of room temperatures, no matter what sort of heating system is installed.

Insulation in a floor that is above open ground, is no less essential than insulation in the walls and ceilings; moreover, curtain walls should be provided to stop convective cooling.

The importance of temperature uniformity is illuminated by the persistent efforts of designers to achieve it. To date, probably the most striking results have been obtained from tests on baseboard convectors. Table 1 offers data on temperature gradients developed by the National Bureau of Standards through tests on this type of heating in a bungalow of four rooms and bath, prepared for the purpose. Report BMS 115 of Building Materials and Structures recounts these tests in full.

However, the excellent uniformity shown in the test house must be discounted to some degree, for the building was erected over a full basement, and the resulting floor warmth contributed substantially to the recorded results. Basements are decided assets to uniformity.

One item of curious interest shown in Table 1, is the indication that the practice of closing off rooms in cold weather actually may *reduce* uniformity. Most thinking has been to the contrary, but again, the recorded evidence may prove nothing beyond the case in point.

Equally small temperature gradients have been recorded by various investigators by use of panels in the floor, ceiling, or walls. However, these radiant panels are peculiarly vulnerable to gradient interruptions by the physical bulk of tables, chairs, and draperies. For example, persons sitting around a table beneath a ceiling panel, may experience discomfort from chilled feet, while conversely, should a floor panel be the heating unit, the head, shoulders, and arms may be the sufferers.

Incidentally, floor panels must be designed with the utmost care to limit

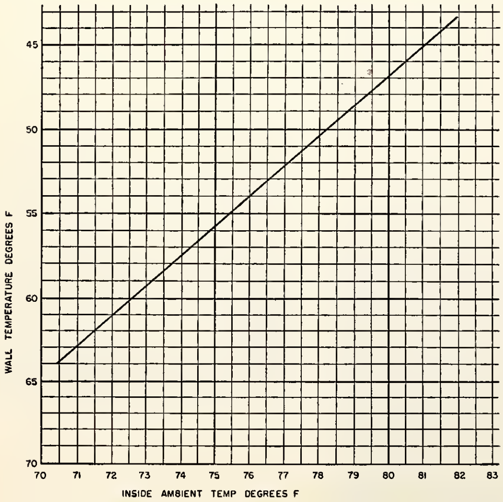

Figure 2—ambient temperatures to counteract radiation losses. This curve is based on the following assumptions: average skin temperature, 82F; effective exposed area, 20 percent of total; optimum losses of a person seated and at rest, 300 Btu per hour by radiation, 107.5 Btu per hour by evaporation and respiration, 22.5 Btu per hour by convection. The metabolic rate totals 430 Btu per hour. The conditions described are considered to represent good design criteria by the author.

their surface temperature to 85F or lower. Heated floors cause the swelling of feet and ankles in certain susceptible persons, the swelling often beginning within two hours after the floor has been entered upon. Tests by the A.S.H.V.E. and other investigators indicate 85F value to be the critical heat.

Uniformity with warm air is always difficult to obtain, and particularly in buildings more than one story high. This writer recommends the use of baseboard supply registers of low discharge velocity, placed in the outside walls. The warm entering air then diffuses upward over the comparatively cold external wall, with a resultant early equalizing of density that retards the generation of stack movement to the upper floors. One manufacturer is now offering commercially a register designed to produce this air diffusion over the outer wall in connection with a high velocity supply pipe. However, high velocity of discharge is not recommended for any register save this special one, else the blow across the floor may become both long and annoying, thereby destroying the uniformity of temperature we are trying to achieve.

A measure of radiant surface is always of value to the establishment of uniformity, consequently the old-fashioned cast-iron radiator performed a useful service not generally available with our recessed and concealed convectors. There is one obvious way to make up for this loss in radiant surface in convector designs which unfortunately is frequently overlooked. We might provide a little more convector surface, say 10 percent more than the calculated load calls for. This treatment tends to be better than the elevation of the water or steam temperature in the convector, simply because the added surface increases the proportion of heated surface to unheated areas. In other words, distribution is improved, particularly if the added surface is obtained by means of a little more length.

Complete uniformity is beyond our skill at this moment, but with careful design and arrangement, we can approach it within five or six degrees, a range that must not be exceeded under penalty of discomfort.

problems of air treatment

A modern development in air conditioning apart from temperature control is shown *(see Figure 3)*. The control of humidity, the filtering from the air stream of pollens and dusts, are established practices and we all are familiar with the machinery these objectives require. However, in this illustration, we observe practical acknowledgment of the need for even greater efforts to achieve comfort. These efforts take the form of virus vitiation by aerosol spray, and bacteria destruction by use of ultraviolet lamps, all encased in the same cabinet that houses the filters and humidifying functions.

The aerosol in this case is a triethylene glycol, but experiments have been made also with sodium hypochlorite and solutions of resorcinal in glycerin. The efficiency of the aerosol depends vitally on maintenance of adequate humidity—from 50 percent to 90 percent relative humidity is generally considered the desirable range. With some aerosols, their effectiveness is impaired seriously with relative humidities of 25 percent or lower.

With the glycol, we must keep an eye on the dewpoint also, for glycol in liquid form is a solvent, and any condensation occurring on furniture or paints will mark them.

The ultraviolet lamps are claimed by their makers to kill at least 95 percent of all the disease-causing organisms that come within the lethal area of their rays, and this claim is accepted by the American Medical Association's Council on Physical Medicine.

While the safest location for ultraviolet lamps is within the duct system, or in a cabinet device as illustrated, the lamps also may be used effectively in open rooms. In these cases, the lamps should be mounted well above the floor and so shielded that direct rays will not impinge on human eyes. The rays should not strike wall paper or draperies in straight impact, either, for their effect is to fade colors.

Cabinets containing both the germicidal sprays and ultraviolet ray lamps are being built currently in standard sizes to handle air at the rate of from 600 cfm to 2500 cfm. Since they provide air washing and humidifying functions as integral features of their air treating duty, they can be used as supplements to heating systems in which air treatment normally is not provided, for example, convector and panel systems.

odor factors

While the presence of a fragrance in the air is not essential to human comfort, we all know that unpleasant odors can destroy it. Odors of all kinds are as real as concrete; activated carbon has been observed to absorb so substantial a burden of invisible smells, as to increase in weight 40 percent.

Odors do not necessarily indicate that the atmosphere is harmful or even stale. Their effects are most frequently emotional or physio-emotional, and in consequence shatter perfect comfort by injecting feelings of annoyance or uneasiness. McCord and Witheridge, in their *Odors: Physiology and Control*, refer to the importance of odors as a cause of neuroses and maladjustment. Psychiatrists have observed that the presence of some particular odor, its balefulness often unsuspected, can be the

TABLE 1: temperature gradients in a test bungalow, inside doors open

Outside temperature F	Air temperature above floor F 2" Above	60" Above	94" Above	Surface temperature of floor	Maximum temperature difference*
5	66.6	70.6	72.4	63.3	5.8
20	67.2	70.5	71.9	64.9	4.7
32	68.2	70.4	71.6	66.3	3.4
50	69.2	70.6	71.1	68.0	1.9
		inside doors closed			
1	65.8	70.0	72.5	62.2	6.7
20	67.4	70.8	72.8	64.5	5.4
32	67.9	70.3	71.7	66.2	3.8
50	69.2	70.2	71.0	68.1	1.8

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* *Difference between 2" above floor and 94" above floor.*

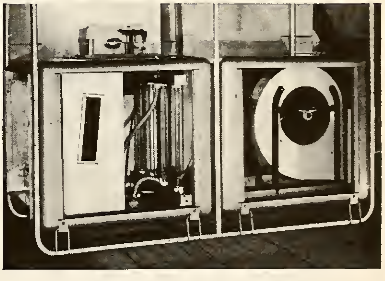

Figure 3, above—before distribution to the living areas, air is treated with a glycol spray and ultraviolet rays in the cabinet to the left of the fan compartment.

CHART I: essential items for winter comfort

Item	Suggested approach to design
Adequate temperature	Select the temperature with allowances made for customary light clothing and bodily radiation losses. Never accept 70F as the comfort temperature unless calculations prove it to be.
Uniformity of temperature	Design must compensate for the non-uniform characteristics of the heating system selected.
Proper humidity	50% relative humidity is thought to be about right. However, humidity in winter comfort is of less importance than is generally understood. Dry air is not unhealthy air.
Dusts, pollens and other allergens	Filtration is effective on airborne motes of fairly large size. Does not usually stop pollens and allergens. Activated carbon might help on these.
Odors	Best removed by activated carbon. Extremely important psychologically.
Cold virus	Glycol aerosols provide a checking action.
Bacteria	Ultraviolet lamps are lethal to many bacteria that come within the effective length of the rays.
Color and decorations	Important both psychologically and physically. Should be designed and arranged by a specialist.
Lighting	Important from a fatigue standpoint. Lighting specialist should be consulted for general guidance in every new building.
Controls	Comfort must be provided automatically. Most persons object to fiddling with gages and switches. Push buttons should be the maximum responsibility placed on the occupants. There is no comfort when responsibility is present.

cause of marital failure; domestic happiness sometimes hangs on the wife changing her perfume.

The implications, therefore, of odors as disturbers of comfort are so far reaching, that we are justified in taking definite action to secure their control.

We have two approaches to the problem. First, we can mask odors by superimposing on them an even stronger odor, illustrated by the burning of incense, or the release of ozone, or the introduction of a deodorizing spray. Second, we can eliminate the odors by water washing of the air, or by passing it through a bed of activated carbon.

The effectiveness of the carbon is shown by studies and experiments reported from the Naval Medical Research Institute. Six commercial agents were tested in an effort to determine the minimum amount of fresh air needed to reduce odors to an acceptable level in a typical ship's compartment. Of these, only activated carbon was effective, and by its use the replenishment air could be cut to one cubic foot per minute per man without producing an undesirable atmosphere.

Mechanical air conditioning alone, as a result of atmospheric moisture condensing on the cooling coils and thereby carrying off odors down the drain also was found to be helpful. Under these circumstances, five cubic feet per minute of fresh air per man produced satisfactory conditions, approximately half of the minimum recommended by the A.S.H.V.E.

Of additional interest, these investigations disclosed that use of masking deodorants did not reduce odor levels, but rather anesthetized the perceptive nerves.

Activated carbon, originally used almost entirely for commercial and industrial air purification, is now being applied against some residential problems, with particular reference to tobacco smoke. Occasionally, we encounter persons who are violently allergic to burning tobacco, and their sensitivity is so acute that other members of the family must forego completely all smoking in the same house. Activated carbon is reported to give considerable relief in some of these cases, at least to the extent that smoking may be permitted in certain rooms if the air is changed and purified constantly. The full scope of carbon's efficiency against allergens is not yet catalogued; it might well be tried in various severe cases.

There is another way to abolish odors that we should understand, although as designers we seldom shall be asked to apply it. This procedure is to introduce a selected perfume into an atmosphere presently contaminated with an identified odor, the characteristics of the two odors being such that in their blending each neutralizes the other and we smell nothing at all. Obviously, application of this treatment to be successful, requires the services of an expert in the chemistry of odors, and is therefore outside the scope of most architects and engineers.

fresh air

Fresh air is recommended as a specific for odors, and yet fresh air is not always essential for healthy living, nor is it always desirable. In the "Donora Incident" of October 30-31 of 1948, probably fewer persons would have become ill and fewer died, if windows had been kept closed. At the time, there was a dense smog present carrying heavy concentrations of sulphur dioxide which at the time of first measurement approximately five hours before termination of the dangerous condition, amounted to 0.54 parts per million parts of air.

The symptoms of discomfort at Donora were aggravated shortness of breath and coughing, mostly in elderly persons with medical histories of respiratory illness or heart disease. The significance of the incident to designers is that fresh air intakes should be arranged for filtration of the air before delivery to the rooms, particularly if we are designing for persons known to have respiratory or cardiac irritations.

Staleness of air is caused usually by a combination of odors and air stagnation. Staleness does not mean that the air is exhausted of oxygen and is unfit to breathe. Time limits for the oxygen suitability of any given room may be computed from the following formula:

$$\text{Hours} = \frac{0.03 \times \text{cubic feet of room volume}}{0.75 \times N}$$

0.03 = 3% of carbon dioxide present, which is the maximum possible without physical reaction.

0.75 = 0.75 cubic feet per hour of carbon dioxide exhaled by the average person.

N = Number of persons in the room.

For example, a room of 1000 cubic feet volume, if completely closed up with four persons inside, might be expected to become uncomfortable after 10 hours. Panting develops with a concentration of six percent reached in 20 hours, and stupefaction at 10 percent or about 33 hours, according to the formula.

Generally, all we need do to relieve staleness, is to deodorize the air and keep it moving. In residences, where comfort concerns us mostly, all the fresh air needed during the heating season leaks in at doors and windows.

color and comfort

Let us consider the effectiveness of color in creating emotion. There is nothing mysterious about the process; it takes place substantially by reason of the natural laws of refraction, with measurable physical responses. For example, red creates a feeling of nearness because

CHART 2

System name	Comfort items integral with system	Additional items needed and facilities present if any
Steam	Simple temperature control.	Temperature uniformity; humidification; filtration; odor control; virus and bacteria destruction; automatic controls.
Hot water	Ditto	Ditto
Gravity warm air	Simple temperature control. Humidification.	Temperature uniformity; filtration; odor control; virus and bacteria destruction, which may be introduced in the air circulating system; automatic controls.
Mechanical warm air	Simple temperature and humidity control. Filtration for dusts.	Temperature uniformity; odor control; virus and bacteria destroying equipment readily introduced into the air distribution system; automatic controls for everything.
Panel heating	Simple temperature control. Good uniformity of temperature.	All else must be added as additional equipment, including some means for changing and moving the air.
Baseboard heating	Ditto	Ditto
Space heater installations	Simple temperature control.	All else must be added as additional equipment.
Electric radiant glass panels	Simple temperature control. Fair uniformity of temperature.	Ditto

Note: Temperature uniformity, except with panel and baseboard systems in which it follows generally as a characteristic of the system, must be provided by the designer. Color and lighting are not integral with any of our present heating systems and therefore must be treated as a supplement to all of them.

TABLE 2

reflective qualities of colors related to black

Color	Heat absorption
Black	0.98 to 1.00
Red, brown, rust	0.80
Yellow, buff	0.70
White, cream	0.50
Aluminum, gilt	0.50

red, in passing through the eye lens suffers comparatively little refraction, and the lens must bulge to focus the red image on the retina. With blue, the opposite occurs, the lens flattening to pull the image forward from in back of the retina, and in consequence blue appears to be farther away.

These characteristics are important to every architect who wishes to produce a sense of size in a small room, or an impression of coziness in a large room. Moreover, the opposite effects of red and blue must be considered in any decoration aiming at comfort, for the combination has a power to create eye fatigue as a direct result of imposing on the eye a constant readjusting action of the lens.

Yellows, purples, and their associated hues, are neither advancing nor retiring, and therefore combinations of these colors in a decorative scheme are literally easy on the eyes.

Since the development of eye strain, whatever the cause, notably affects human comfort, sometimes producing headaches that may be blamed on foul air and at other times simply causing a feeling of fatigue with attendant chilliness, plus considerable irritability, the collaboration of the architect and the decorator should be regarded as essential. For the same reason, the lighting scheme of a room should be discussed with experts, prior to the laying out of the wiring and equipment.

The capacity of a color to create sensations of warmth and coolness does not reside merely in our minds, but actually exists. Maximum heat absorption by radiation is achieved by a wholly black surface, such as lampblack. In comparison, the light and reflective surface of aluminum insulation when held close to the cheek, produces an immediate sensation of heat, indicating that much of the heat radiated by the skin is not absorbed by the metal, but turned back whence it issued.

All of our colors fall somewhere between the profoundly light and profoundly dark, and although the texture and shape of the surface affect its ability to reflect or absorb heat, the relative positions of light and dark are well established on the reflective scale. Table 2 shows values suggested by the A.S.H.V.E., and since we are primarily concerned at the moment with color, it will be observed that the lighter hues invariably are more reflective.

Obviously, a light colored room will reflect heat emitted from radiators, convectors, our own skins, and this fact is acknowledged in our conventional coupling of the adjectives "bright" and "warm." Conversely, we often speak of a room as being "cool and dark" or even "dark and dreary."

From the design and decorative standpoints, bright warm colors might well be chosen for comfort in northern latitudes and cold climates; cool dark colors for warm seasons and regions.

Basic color schemes and their effects may be described thusly:

a) Monochromatic: means done in a single color, with perhaps some touches of white, gray, or black. Decorators do not recommend this scheme for rooms that are much, or continuously, lived in, since the ultimate effect is tiresome.

b) Analagous: this plan employs a harmony of related colors, frequently expressed in shades of the same color. The effect is pleasing, but may tire some individuals in time.

c) Complementary: colors of complementary hues are considered by some decorators to produce the best effect of all. However, care must be exercised in application, since too strong a contrast, as of red and blue, tends to produce eye strain. There is also an optimum relationship between the areas devoted to warm and cool colors, with the larger areas generally preferred in cool hues.

all this and what else?

Complete comfort to the average American who is our client, means freedom in his home to rest, relax, and do as he pleases in an atmosphere that has been purged of drafts, smells, noises, sneezes, chills, overheating, excessive dryness, excessive humidity, hostile bugs, viruses, and bacteria. He wants all these blessings and one more, this ultimate comfort being expressed by a client of the writer in exactly six words. Said this man in discussing the projected design of his new, all-year conditioning system:

"Remember, I want comfort without bother."

Comfort, then, must be automatic to be complete.

the summing up

The essential considerations for winter comfort plus a directional guide for their provision, are tabulated in Chart 1. What we obtain as a matter of course with our various heating systems and what must be added to produce complete comfort with each, appear in Chart 2.

These charts are based on ideas and equipment presently recognized. Developments of the future probably will bring to us a wider and better application of solar heat together with a more common use of glass that passes the violet rays in sunlight. Panels may be expected to migrate to some extent from floors, walls, and ceilings, and take on the forms of door and window trim, moldings, and even to occupy the doors themselves. We may see them, and feel them, sooner or later in the furniture on which we sit.

As for color and air sanitation, the day some large operational builder makes them components of his basic design and advertising, is the day complete comfort will begin to enter our medium priced homes.

Choosing the Right Heating System

The basic advantages, limitations, and characteristics of the principle heating systems are discussed in this article. The author's comments and conclusions, presented in chart form, serve as a helpful reference for the architect selecting the most suitable system for a particular job.

What is the cheapest heating system?

Cost studies, on a wide variety of jobs designed and handled by the writer during the past three years, indicate that warm-air heating, on the present market, requires a substantially smaller capital investment than either circulating hot-water or steam systems. For schools, churches, fire-stations, residences, and other structures examined in this study, the average cost ratios, assuming warm air to have a value of 1, were 1.5 for circulating water and 1.65 for steam.

While these ratios may be expected to vary with particular designs and with changing market conditions for material and labor, they have obvious value for every architect and engineer who must discuss costs with a client. Redesigning a system can take all the profit out of a job, and to do so is particularly undesirable after structural plans are drawn.

Chart 1 is presented as an aid in estimating the cost of a central heating system for several types of structures. Note the influence of layout and construction materials on the costs, as evidenced by the investment range for any one class of heating.

To help us with our predesign discussions of heating systems, suppose we consider the peculiar advantages of each. With a warm-air system, for example, the freeing of floor space, and the adaptability of duct layouts to all-year conditioning are obvious. Not so obvious is its peculiar suitability to special conditions. Warm air under pressure from a fan, we know, can be directed downward with ease, and where floor space is precious, a heater in the attic literally can lift its load right off our worried minds.

Figure 1 illustrates a type of horizontal heater, originally developed for suspended installation, that fits admirably under the low rafters of a sloping roof. Since fire departments regard these high-set heating plants with definite favor, we are likely to see more of them as basementless houses increase in number.

Figure 2 shows the design of a warm-air system intended to hide all heating equipment in an historic synagogue. Main ducts are run under the floor, and the two stacks to the balcony are built into the walls.

Less favorable as a general rule is the consideration of warm-air heating, with the fan in a central position, for a group of buildings. The duct layout becomes bulky, lengthy, and involved—all undesirable features. An efficient air balance in such a system is all but impossible; other ways of heating will be simpler and better.

We can also advise our clients that warm air is not often our best choice for old buildings. Usually, the need for structural changes tends to complicate the installation and run up the cost. Alternately, the sight of exposed ducts will also be objectionable.

The Hot Water Picture

Why do we use hot water? To say that our client likes it and wants it is not an adequate answer. In many circumstances, hot water is the ideal medium.

For example, suppose we are faced with the necessity of concealing all piping, and the structural design is such that horizontal runs must be laid flat. With these requirements, the small piping needed for hot water, the absence of insulation requirements except in outside walls, and the exemption from gravity drainage demands, make circulating hot water our most suitable selection.

Another advantage of hot water is its ability to support uniform temperatures. We have quite close control of the temperature in our radiators, and the heat storage in the water maintains heat emission during "off" periods of the firing equipment. Whereas with steam, hot water's major competitor, we are

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* *Consulting Mechanical Engineer, North Charleston, South Carolina*

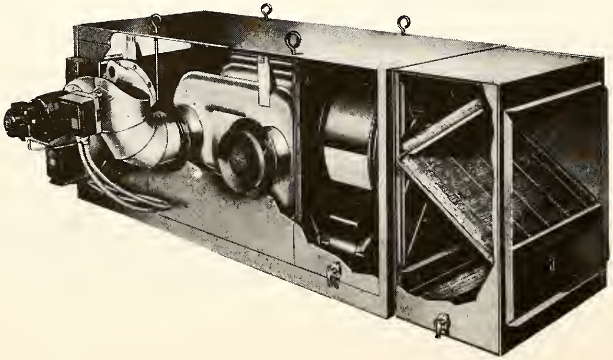

Figure 1. Horizontal type heater is suitable for installation under low rafters of a sloping roof.

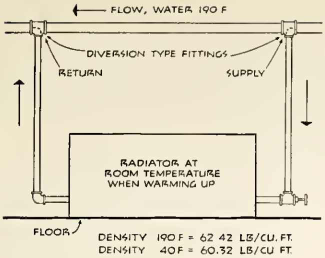
FLOW, WATER 190 F
DIVERSION TYPE FITTINGS
RETURN
SUPPLY
RADIATOR AT ROOM TEMPERATURE WHEN WARMING UP
FLOOR
DENSITY 190 F = 62 42 LB/CU. FT.
DENSITY 40 F = 60.32 LB/CU FT.

Figure 3.

Figure 4.

often conscious of the radiation cooling, when the furnace operates on an "off and on" schedule. We seldom perceive this change with hot water. Where control of temperatures within close limits is desirable, as in nurseries, hot water offers definite advantages.

From the standpoint of limitations, we must recognize that 1) hot-water radiation must provide more surface than steam due to its normally lower rate of heat emission per square foot; 2) a multiplicity of zones tends to produce a multiplicity of piping and pumps; and 3) friction and pipe sizes must be carefully considered or the system's balance will be faulty and the heating unsatisfactory.

For the architect concerned with space, the added areas of hot-water radiation is not a serious problem, for the ratio of 195F water with an emission of 200 Btu. per square foot per hour, to steam with 240 Btu. emission, is only 1.2 to 1. Of course, with the obsolete gravity circulation systems that we prefer not to design for modern buildings, the ratio was much greater—1.6 to 1 being the accepted ratio. Generally, in modern design, the added area is readily acquired by increasing the height or number of tubes in the radiator.

Multiplicity of piping is of no im-

CHART 1: UNIT HEATING COSTS FOR ESTIMATING

building class	building description	heating system	load per hour, btu.	investment per M, btu.
Residence	Frame, 1-story, 10 rooms	Mech. Air	138,000	$ 9.78
Residence	Concrete block, 1-story, 5 rooms and bath	Mech. Air	82,000	12.13
Residence	Brick veneer, 2-story, 8 rooms, bath, and attic	Mech. Air	140,000	11.72
Residence	Frame, 3-story, 10 rooms, 2 baths	Circ. Water (Reversed Ret.)	200,000	18.00
Church House	Brick, plaster finish, 2-story, including auditorium	Circ. Water 2-zones, single pipe	300,000	12.80
Y.W.C.A. Group	3-brick and frame dormitories, from 2 to 4 stories, extended over a city block, with underground piping	Circ. Water 3-zones, reversed return design	800,000	11.27
School	Brick, 1-story and auditorium, shaped like letter F	Circ. Water 4-zones, reversed return	958,000	7.52
School	Brick, 3-story and auditorium, shaped like letter L	Circ. Water 3-zones, reversed return	824,000	16.61
School	Brick, 1-story, compact under one roof	Steam, 2-pipe	1,300,000	8.46
School Group	Brick, 1-story, 4 classroom wings, separate cafeteria, separate library bldgs. Cover a full city block	Steam, 2-pipe underground mains	1,100,000	13.64
School	Brick, 1-story, compact, one roof	Mech. Air	400,000	11.50
Synagogue	Solid brick, balcony	Mech. Air	300,000	11.67
Fire Station	Brick, 2-story, 3 trucks	Mech. Air	190,000	9.00

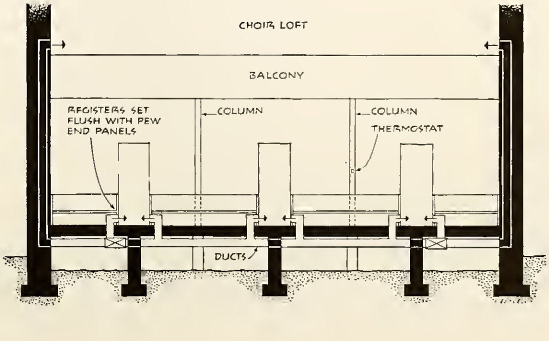

Figure 2. The warm-air system in this structure was designed to hide all heating equipment.

portance in a boiler room with plenty of space, but it can present problems of trench size and interference, if the distribution is extensive. In these circumstances, costs may approach those of steam systems. This trenching and interference factor was a strong agent in causing the writer to use steam for a large group of school buildings in Florida.

Another sometimes troublesome factor, for radiators below the level of the main, is the resistance to the starting of circulation. The reason for this becomes obvious if we look at Figure 3 and realize that we are trying to push cold, high density water *upward* and out of the radiator with hot, low density water moving *downward*. In short, we are challenging a law of nature. Dense fluids seek the bottom of a container, and lighter fluids the top.

The best way to handle this situation is to avoid it. If many radiators must be located below the main, some other type of heating should be considered. However, for the occasional low radiator, we can secure adequate results by inserting a mechanical contrivance in the main at the point of radiator take-off. This fitting is designed to force a predetermined quantity of hot water downward into the radiator.

Since these diversion fittings add to the cost of the job, contractors in a highly competitive market may tend to leave them out. To avoid this possibility and later grief, specifications should demand them.

What About Steam?

Where extensive distribution is concerned, steam is our number one choice. Generally, we can expect it to go anywhere, provided that there is enough pressure on the boiler. District steam companies have been making a living from this characteristic for years.

Steam also permits us to use the smallest sizes of heat-emitting equipment, such as radiators, convectors, and unit heaters.

Where large groups of persons congregate, and especially if they congregate in irregular numbers, the sharp "off and on" control possible with steam is of definite advantage. We can heat and cool without the complication of the heat lag as in a body of hot water. Steam is quick and very positive.

On the other hand, the limitations of steam tend to be rather critical. For example, adequate drainage of the mains, by gravity, is essential. To provide the $\frac{1}{4}$-inch per 10 feet of slope of the steam main, and the $\frac{1}{2}$-inch per 10 feet of slope for the return, is sometimes difficult and costly. It is sometimes impossible.

Next, steam piping with its insulation presents a problem of physical bulk, not always accommodated with ease.

As a final item for thought, steam heating tends to be the most expensive method we can choose. This dollar factor grows under our very eyes in basementless houses, where return of the condensate to the boiler by gravity is impossible, and we must provide sumps, pumps, and perhaps a pipe trench under the floor.

Panel Heating

We have a choice of heating media for our panels: hot water, warm air, or electricity. All three have a common characteristic in that they are primarily applicable to new buildings only, and must be incorporated in the construction.

The effect on room occupants is largely the same. As floor temperatures must be limited to 85F, supplementary ceiling or wall panels are frequently necessary to overcome winter heat losses. Such panels tend to complicate the installation. Indeed, many designers lean to ceiling panels exclusively, to take advantage of the higher permissible temperatures.

Panel heating costs more to install than conventional radiation. There is a conviction that operating costs are lower because of the nature of radiant heat. This writer considers such beliefs unwarranted at the moment, however, due to the many variables involved in any given installation. For instance, rugs, drapes, and the placement of furniture, introduced after the system is in operation, may completely upset the operating economy. Heat rays will not pass around corners. Figure 4 shows a wall installation for a hot-water panel.

Operating figures for electric panels used in the Pacific Northwest states are quite reasonable. In Seattle, the owner of a five-room house with attic reports a winter average of $13.75 per month for heating; a 1400-square-foot residence in northern California was heated with full comfort for $20 a month.

The electric cables, well insulated, may be located in the floors, ceilings or walls, and the current input is controlled by thermostat. The number of installations is increasing, with several hundred now in the Seattle area alone.

Figure 5 illustrates the ceiling construction involved, if we heat with a warm-air ceiling panel. The basic idea is to build a warm-air chamber over each room wherein air movement is guided by metal baffles or channel-forming partitions. At present, this system is being recommended for one- and two-story houses; however, it seems suitable anywhere, if we can get the air to the chamber.

Baseboard Radiation

It is sometimes difficult to provide enough baseboard radiation to meet the heat losses from rooms with large exposures. For example, if we have a room heat loss of 8000 Btu. per hour, we must place 16 feet or more of steam baseboard, and 20 feet if the medium is 195F hot water. Considering that wall area must be allotted to doors, closets, etc., the situation sometimes becomes critical.

Baseboard radiation definitely conserves space, and can be made to present a good appearance. It responds quickly to weather changes. It is not cheap to install. From an operating standpoint, circulating water temperatures should be kept below 200F in order to avoid the development of dust streaks on the wall above.

Gas Fired Wall Radiators

Figure 6 shows a more or less recessed wall radiator, gas fired. As these units only cost about $100 each, their adoption for small, one-story houses offers a definite investment saving with adequate heating. As the gases of combustion are vented outdoors, odors and water vapor in the rooms are not observed. These units appear to have definite advantages in regions isolated from electricity, but in which "bottled gas" is available. They are immune to storms that might disrupt service of electrically actuated units.

Floor Furnaces

A gas-fired, or oil-fired floor furnace can be provided for around $200, including oil tank and connecting piping. Some of these units have an air-circulating fan, others depend on gravity.

The conventional floor furnace is of small size; usually it will have a top output of 50,000 to 60,000 Btu. per hour.

In the experience of this writer, they do not create warm floors, as is sometimes claimed. In fact, movement of air back to the heater has been observed to produce a noticeable draft at floor level.

Tests on temperature stratification at the National Bureau of Standards, Washington, D.C., indicate a 20F differential between the floor and ceiling for gravity circulation, and 10F if the heater is fitted with a fan

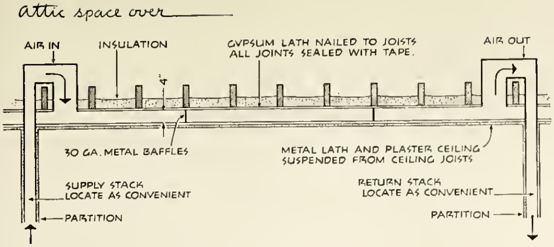
attic space over
AIR IN
INSULATION
GYPSUM LATH NAILED TO JOISTS ALL JOINTS SEALED WITH TAPE.
AIR OUT
30 GA. METAL BAFFLES
METAL LATH AND PLASTER CEILING SUSPENDED FROM CEILING JOISTS
SUPPLY STACK LOCATE AS CONVENIENT
RETURN STACK LOCATE AS CONVENIENT
PARTITION
PARTITION

Figure 5.

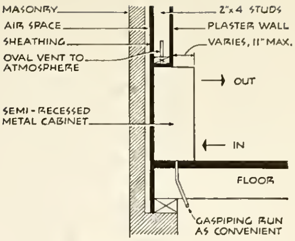

Figure 6.

and the returns are run under the floor.

Heat Pumps

An ordinary five-room house will require approximately five tons of cooling equipment, and for frame construction, 50,000 Btu. per hour for heating at 20F outside temperature. A heat pump for these requirements, at $800 per ton means an investment of $4000.

According to Table 1, which has been compiled from manufacturer's data, this five-ton unit is going to be short on the heating side if the outside temperature drops below 20F. If we live in a 0F climate, we must buy a larger heat pump, or alternatively find another source of heat rather than outside air. Water or earth is good, since city water seldom falls below 40F, and we can always dig below the frost line of the earth.

Operating figures on a five-ton unit in St. Petersburg, Florida, retail clothing store, show that $29 per month was enough for an average winter month, where the average minimum temperature is about 40F.

Radiant Glass

Radiant glass units are being built in 1000 watt, 220 volt, 4½ ampere sizes for permanent installation, or with 110 volt, 9 ampere ratings for auxiliary heating in existing buildings.

Investment costs will average around $95 per unit. Operating costs will vary with local current rates and the hours of use. The manufacturer offers the following formula for estimating operating costs:

$$\frac{\text{Tot. cu. ft. x degree days x 0.2}}{1000} = \text{Total kw-h}$$

In dollars and cents, this means about $12 to $13 a unit for a climate having 2400 degree days in a heating season, and an electric rate of 1.65 cents per kilowatt hour. Colder climates and other current rates should be estimated in proportion.

CHART 2: SUMMARY OF HEATING SYSTEM CHARACTERISTICS

heating agent	especially suited	less suited for	comments
Mechanical Warm Air	(a) All-year conditioning (b) Low investment (c) Buildings without basements (d) Where air filtering and humidifying are necessary (e) For radiant ceiling panels (f) Attic installation of heater	(a) Lengthy duct runs (b) Old buildings (c) If duct space is critical (d) If duct appearance is ugly (e) For separated buildings	This means of heating is developing favor in homes and small buildings
Forced Circulation Hot Water	(a) Even temperatures (b) Radiators and convectors (c) Radiant heating in floors, walls, and ceilings (d) Baseboard radiation (e) Where small pipes are essential (f) Where gravity drainage is not practicable	(a) Sharp off and on control (b) Less heat output from unit heaters (c) For involved underground distribution (d) Basementless houses (e) Radiators below the hot water main	Properly designed and installed, hot water is always satisfactory
Steam	(a) Sharp off and on control (b) Unit heaters (c) Extensive distribution systems, underground, etc. (d) Public buildings with widely varying occupancy	(a) Where gravity drainage absent (b) Radiation below boiler water line (c) Basementless buildings (d) If low cost is essential	District steam in a neighborhood may be a deciding factor
Panel Heating	(a) Eliminates all heating equipment from a room (b) For new construction (c) May possibly reduce operating costs (d) Saves floor space	(a) Costs more than conventional systems to install (b) Low floor temperatures limit load acceptable on floor only (c) Old buildings	Use of this system is spreading. Is theoretically excellent
Baseboard Panels	(a) Responds quickly to outside temperature changes (b) Saves floor space (c) Is unobtrusive	(a) Water temperatures over 200F tend to streak walls (b) Not cheap to install (c) May be difficult to meet high heat demands if wall space is limited	
Gas Fired Wall Radiators, Recessed or Corner Style	(a) Heating of individual rooms as units (b) Isolated locations (c) Low-cost installation. Total less than a central plant warm-air system	(a) Buildings having vent problems. A number of pipes from roof or walls is not pretty (b) Vents in rooms deteriorate the room air	
Floor Furnaces	(a) Small buildings (b) Where minimum cost is paramount (c) Saves floor space	(a) Uniform room temperatures (b) If floor drafts are unacceptable	
Heat Pump	(a) Eliminates chimney (b) Reduces fire hazard by eliminating combustion (c) One piece of equipment both heats and cools (d) Automatically goes from heating to cooling cycle instantly as needed	(a) Comparatively expensive to install (b) Heating demands may govern size of unit	
Radiant Glass	(a) Room tempering loads at beginning and end of season (b) Mild climates (c) Low electric rates (d) Low initial cost of installation	(a) Heavy and continuous heating (b) High electric rates tend to make uneconomical	

TABLE 1: HEAT OUTPUT OF HEAT PUMPS*

temperature outside air F	btu. per hour 3h.p.	5h.p.	7½h.p.	10h.p.
20	30,400	50,600	75,900	101,000
30	33,400	55,500	83,300	111,000
40	36,700	61,000	91,500	122,000
50	40,200	67,000	100,500	134,000

*Using Atmosphere As Heat Source

Figure 1—floor plan shows locations of gas-fired unit heaters for short-use church. Gas-steam radiators heat the Pastor's and secretary's offices.

Principles and Violations of Church Heating

BY ROBERT H. EMERICK*

Two unusual but vital factors guide our approach to church-heating design.

First, all church monies are provided by voluntary, and sometimes uncertain, contributions from parishioners. This means that a lack of funds is a constant and well-established church ghost.

Second, the hours of heating, depending on the particular church considered, will range from two hours per week, for a single service, to almost continuous heating for a church that remains open between services for personal worship and meditation. This means that fast heating is desirable for a brief use of the facilities, while some form of partial or area heating should be provided for the open-door condition.

These factors create the first principle of church heating, which is: *provide economy in the design.*

The spending money of one church, for example, comes from 450 families; more than half of these families contribute less than $1 per week per family, and only three of them can be counted on for as much as $5 per week, or more. Also, these are weekly averages taken over a full year; many times, the income drops substantially as individual families meet sickness or other immediate obligations. This is a relatively large and affluent church; nevertheless, there simply is not enough *sure* money available to allow an elaborate heating system. In short, any design that violates this first principle is asking for rejection.

Figure 1 illustrates an application of the utmost economy for a short-use church. Ornamental grilles conceal gas-fired unit heaters and acoustically lined ducts satisfactorily reduce fan noise. From an investment standpoint, there is seldom a cheaper way of heating than this one; in some areas of the country, however, gas fuel is expensive and, for a church with medium to long hours of use, the operating cost may soon nullify the investment saving.

The second principle is a requirement so obvious that only its frequent violations require us to consider it in some detail. It is: *provide uniform heating, without drafts or hot spots.*

Usually the designer, if he is a professional, knows all about uniformity in heating. Unfortunately, he sometimes allows church authorities to convince him that short cuts must be taken to save money or space.

Figure 2 shows a heating system that was abandoned eventually, on orders from the church authorities, in favor of Figure 3. The latter arrangement clipped $6000 dollars from a $14,000 installation: and also clipped heating satisfaction since the back of the church, where the air in the underfloor plenum was comparatively stagnant, remained much cooler than the altar end.

Figure 4 illustrates another way that violates heating uniformity. In this arrangement, the warm-air supply is being forced to go too far and remain warm too long. The employment of return-air grilles at regular intervals throughout the full length of the church, cannot overcome the trouble since air, like water, takes the path of least resistance, and the returns near the heater will do most of the work.

In this church, the installation of a few radiant-glass, electric-heating panels at the chancel end would contribute substantially to better and more uniform heating. Although electric panels would create a hybrid system of heating, one should not hesitate to combine varied heat sources to achieve a harmonious effect.

Problems of draft can be difficult to solve when warm air, introduced into the

Figure 2—underfloor plan of proposed heating system. Warm air enters church through registers located in ends of pews on side aisles; entire underfloor space serves as return plenum. When needed, steam grid under nave provides booster. Branches to apse and transept not shown.

Figure 3—underfloor plan of unacceptable solution. This method was intended to provide a radiant floor using warm air as the agent. As the back of the church remained cool, the design did not furnish uniform heating.

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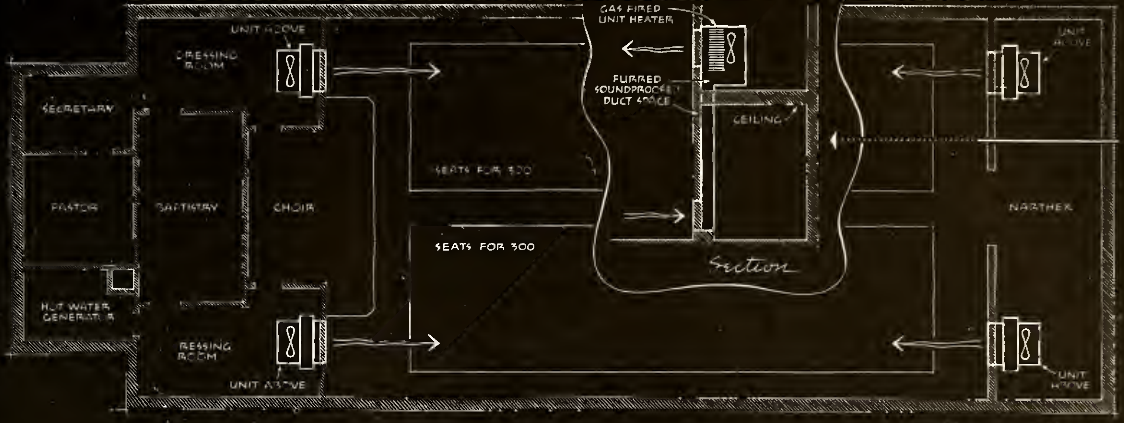
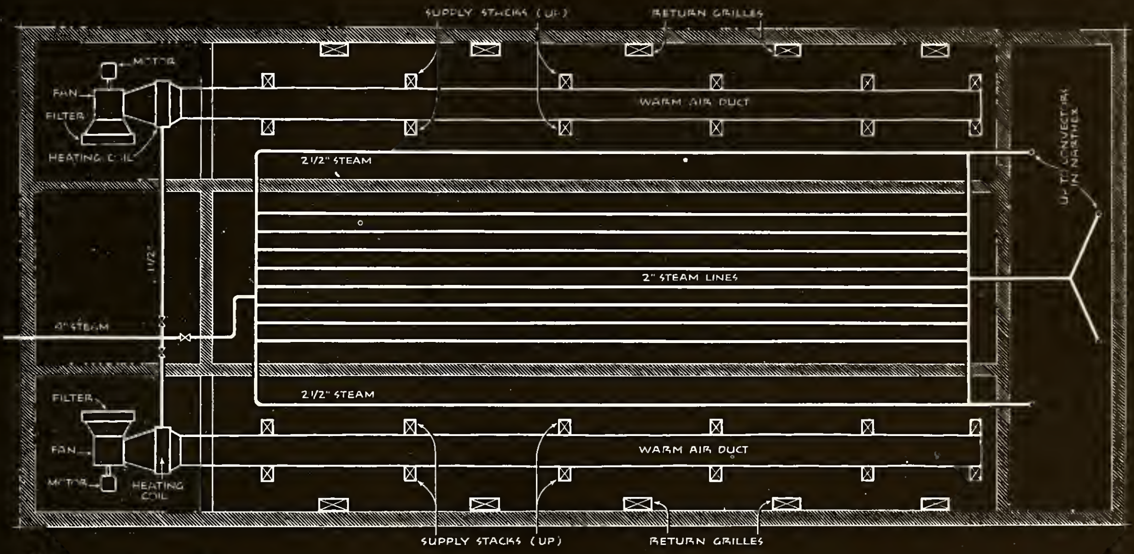
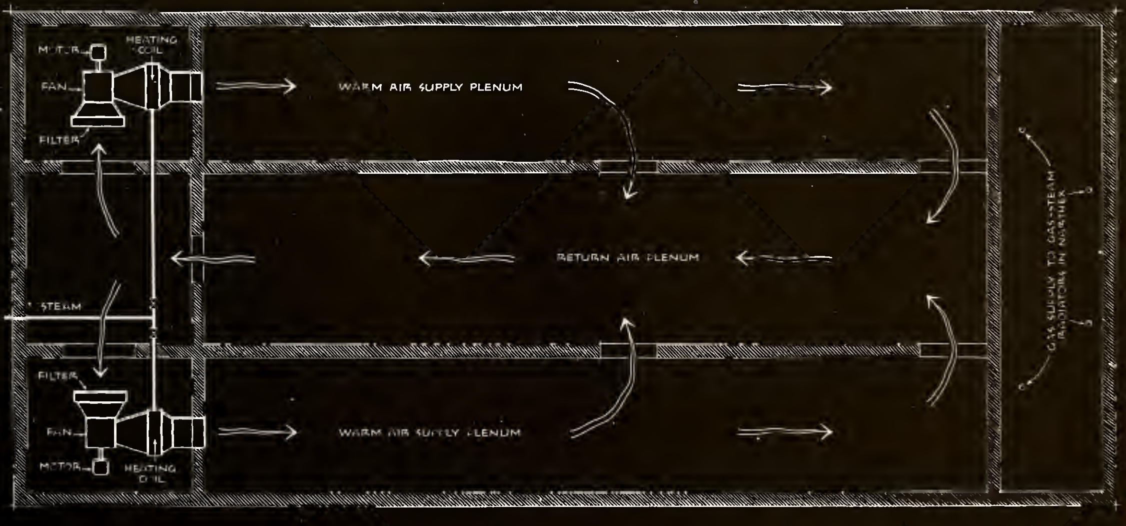
* *Consulting Mechanical Engineer, North Charleston, South Carolina.*



Floor Plan



Underfloor Plans



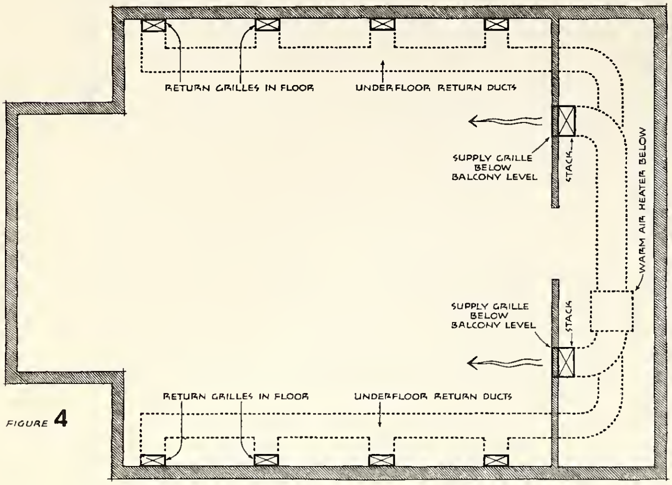


FIGURE 4

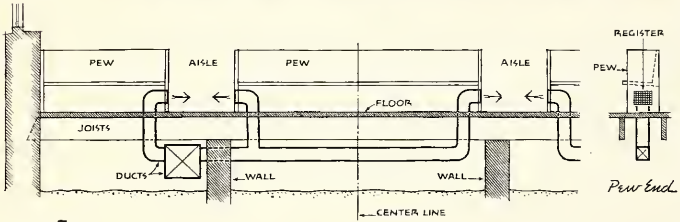


FIGURE 5

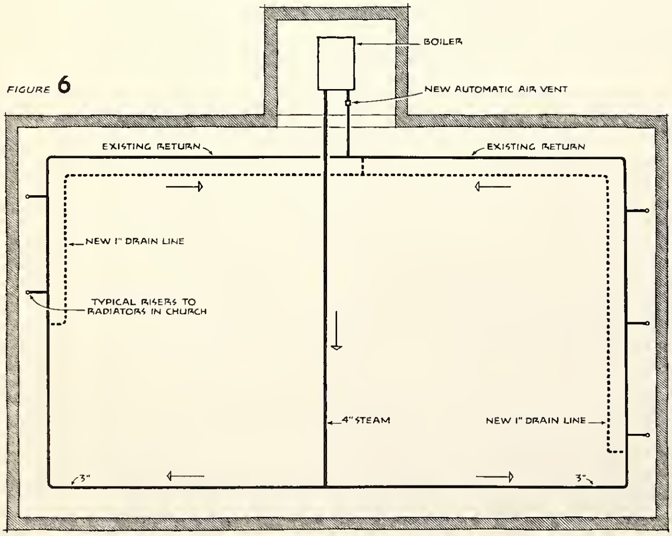


FIGURE 6

church, is the heating agent. To provide every pew with warm, still air requires skillful engineering, and is seldom wholly achieved. Figure 5 illustrates a method used by this writer with considerable success. The warm air is introduced into the aisles from registers so arranged in the end panels of the pews that air streams from opposite sides of the aisle collide and merge, losing their velocity in the collisions. This arrangement also eliminates large, unsightly grille openings.

The third principle of church heating is: *provide heat without noise.*

Steam and water systems rarely offend in this way, although water hammer in an improperly designed steam system can be extremely irritating. To avoid this condition, the designer must provide generous pipe-line drainage; the presence of hammer is a proclamation of poor design, poor installation, or both. Of course, hammer can develop years after a system is installed, as the ultimate result of building settlement or system sag. In either case, correction is neither difficult or expensive. For example, the one-pipe steam system illustrated in Figure 6 gave a great deal of annoyance to the church it served until loop drips were provided at the points shown. Thereafter, the heating was not only quiet but was also more efficient and the boiler was no longer forced. One-pipe systems are particularly susceptible to the development of water hammer as a result of building settlement; they are also particularly favored by many churches because of the comparatively low initial cost.

Noise in forced-air heating systems originates primarily in the fan, although oil-burner sounds are not unknown. This fan noise often causes a church to reject unit heaters for a more expensive system, despite painful, financial stringency. If the unit heaters can be arranged with sound-treated, short ducts, as shown in Figure 1, the problem is easier to solve. Units with the lowest practical decibel rating should be obtained—and one need not accept the manufacturer's guarantee blindly. A commercial sound meter that reads directly in decibels enables one to check the claimed ratings, after the unit is installed. The A.S.H.V.E. recommends a maximum allowable noise factor of 30 decibels in churches.

Sound lining for ducts should extend for a distance of at least 10 times the greatest diameter of the duct, beginning at the noise source, or heater. A minimum thickness of ½" is necessary, since the principle of sound absorption is to trap the vibrations in multitudinous crevices and caves. In a thinner material the caves are too shallow to be effective.

The transmission of noise can often be

effectively stopped by the insertion of a fabric joint between the heater and the duct. Its purpose is to interrupt the harmonious transfer of vibrations across a metal-to-metal joint.

Velocity noises through ducts and grilles do not occur if the designer holds air speeds to the following feet per minute values: main ducts, 900; stacks, 500; grilles and registers, 500.

The fourth principle of church heating is: *the heating system must not offend the architecture.*

In their efforts to observe this principle, some designers have stuffed heating plants into closets and under stairs, demanded the passage of air through ducts too small for the volume required, set radiators behind barricades which thoroughly imprison the Btu, and finally, have provided chimneys of junior size where a senior structure was essential. Fortunately, by some careful thinking, the designer usually can avoid offense and at the same time provide adequate heating.

Church chimneys create special design problems. More important than our desires, is the basic fact that a simple chimney will fail in its purpose if it lacks height. Height provides the natural draft that pulls air into the fire for combustion. Height compels fumes and cinders to journey far above our heads before finding their freedom. For architectural harmony, height may be lessened if we substitute draft fans, but the amputation can be a potential neighborhood nuisance.

So far as heating equipment is concerned, probably the least conflict with church architecture occurs if we use some form of panel heating. This practice is being viewed by designers with considable favor, but caution is recommended. If the service ritual involves much kneeling, individual worshipers may object here and there to alternating a dozen times an hour between the desert warmth of the floor and the comparative coolness of standing. The fact that radiant floors are satisfactory in many churches is no guarantee that such floors will be satisfactory in every church. Before adopting this plan, we should evaluate operating experiences in churches *of the same denomination* for which we are designing.

Much can be done with baseboard radiation, particularly if no supplementary heating is needed. In 23 churches brought to the attention of this writer from various parts of the country, four indicated the need for heating assistance from another source. Extremely interesting is the unanimity shown in selecting the peak-period helper: it was a unit heater in each case. Manufacturers of baseboard equipment might do well to develop thoroughly documented data on their equipment performance in religious buildings, with particular reference to the basic requirements discussed in this article.

The fifth principle of church heating is: *design for simplicity.*

The sexton of a church is a busy man. Occasionally he is equipped with a flair for mechanics and an interest in machinery; more often, however, the less he must do with a heating system, the better he likes it. In consequence, the average system is asked to run year after year, providing comfort to every exacting pew-occupant in the church, and without any mechanical considerations whatever.

Since this treatment is the rule rather than the exception, we certainly should not install a control system that will be made inoperative, perhaps during the first season, by the vibration of passing traffic. It is far more likely to be excised than repaired. Nor should we seek the utmost operating economy with a multiplicity of dampers, bypasses, or regulating valves, for they are quite sure to assume fixed positions eventually, and the heat, as directed by the sexton, will be either off or on. In short, a simple, sturdy arrangement is what we want for long and probably neglected service.

Suppose we discuss the application of these principles to the Temple Beth Israel *(plan on following page).*

A firm decision will not be offered, since decisions always emerge from studies too extensive for our present space and time, but the reasoning that leads to the adoption of one system or another will provide a signpost of method.

First—economy. Since unit heaters cost least if gas fired, we study the plan to spot suitable locations. There are none of these in the sanctuary and but two possibilities in the social hall, both dependent on the availability of wall space above the chair-storage rooms. Dressing rooms and all the other small offices, classrooms, and kitchens are still to be heated. The verdict is not favorable.

Our next thought is to use a forced circulation warm-air system, with basement ducts and baseboard registers. A disadvantage is observed in the need for large ducts—can their bulk be tolerated in the basement? We can use registers in the pew ends, discharging toward the decorative windows, thereby achieving a kind of perimeter heating. If there is no basement under the temple, the application of air becomes more complicated, but obviously this arrangement merits our more exhaustive study.

The combination of radiant floors in the sanctuary, using forced hot water, and convectors in the other rooms, offers another approach. But the writer doubts if a heated floor would be satisfactory in the social hall during dances, the warmth underfoot tending to produce foot fatigue earlier than other forms of heating.

Next, consider the second principle, the importance of uniformity in heating. The design of this structure is such that uniformity is not difficult to obtain. Except for the choir space, it is notably free from offsets, alcoves, and cubby holes. In consequence, forced warm air, a radiant floor, or the judicious locating of convectors will meet our needs on this score.

The question of noise, the third principle, is answered largely by the location of the heater room. Noise weakens as it travels (called attenuation in duct systems) and its journey from the heater room to the sanctuary outlets is a long one. For the registers at the ends of short runs, the use of a fabric interrupter joint and, perhaps, the insertion of acoustical material inside the duct, should assure comfort to all ears. If we use steam or hot water instead of air, the noise problem is simplified to the provision of a properly designed system.

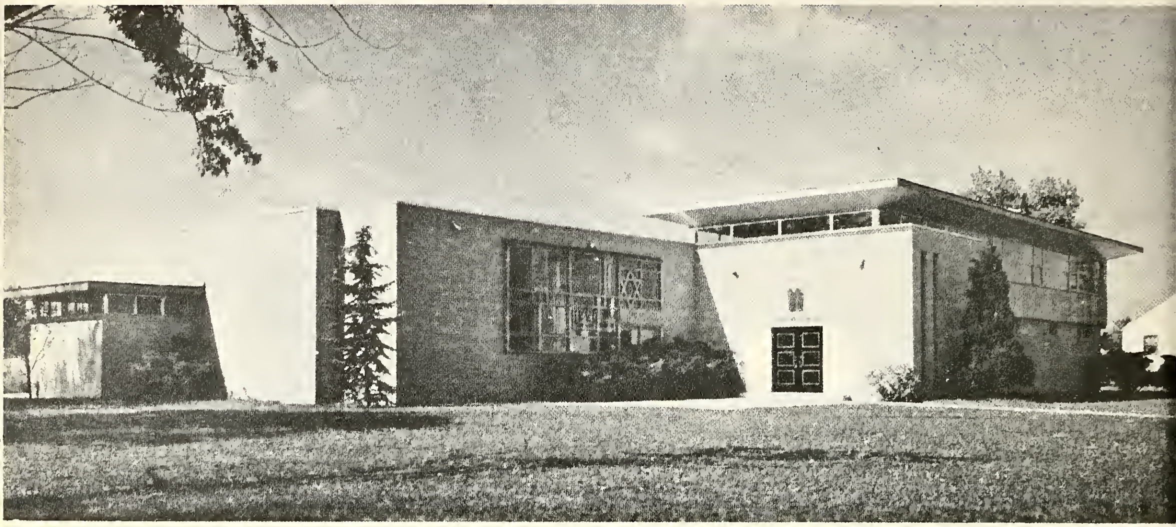
Considering architectural harmony, the fourth principle, we need have no visible ducts in either the sanctuary or the social hall, and the registers, as we have already observed, will be in unobtrusive positions. If we go to a radiant floor in the sanctuary, the problem does not exist. The adoption of convectors, however, will suggest the need for recessed construction or, if this is not practical, a fitting-in of their physical bulk. Fortunately, the seating in the sanctuary is arranged with side aisles adjacent to the outside walls; when the pews extend into contact with outside walls, comfort in these extreme seats is most difficult to provide. This writer would consider the employment of baseboards along these outside walls, with the possible addition of cabinet convectors backed up against the last row of pews and discharging toward the foyer. By such a design, we observe the bold precept of making important what must be seen.

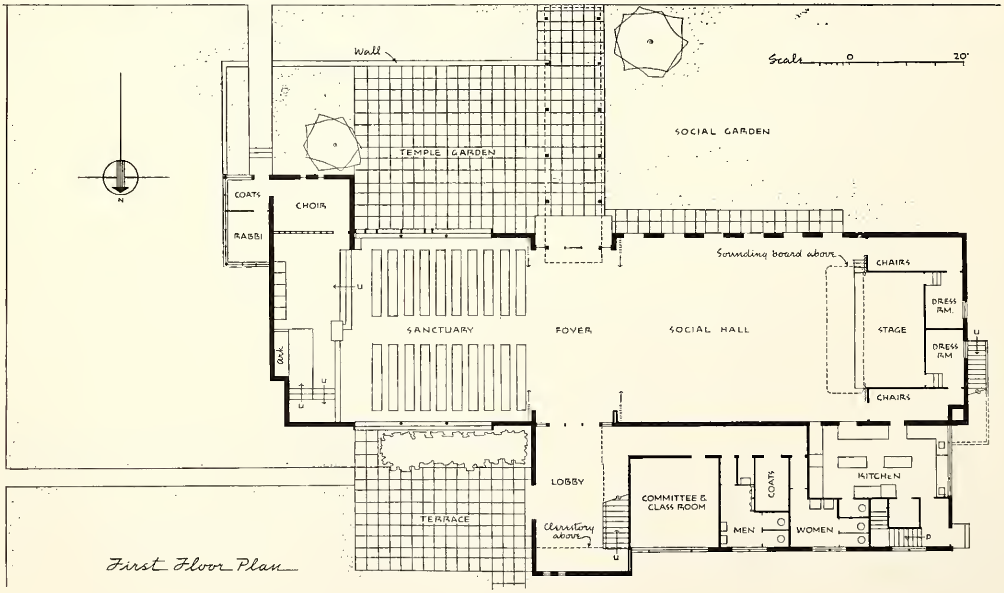
Our fifth principle, the need for simplicity, must be viewed in the light of operating practices. The entire building, with the exception of the rabbi's study, probably will not be used during the daytime hours more than one or two days a week. The sanctuary will be used for services Friday nights and Saturdays, but the social hall and other rooms are likely to house activities during most of the nonreligious evenings.

Obviously, some kind of sectionalized or zone operation is indicated. For the warm-air system, this would involve a two-speed fan and motor-operated dampers; for

TEMPLE BETH ISRAEL, LIMA, OHIO

architect | Percival Goodman
associate architects | Thomas D. McLaughlin and John J. Keil
general contractors | Green and Sowyer

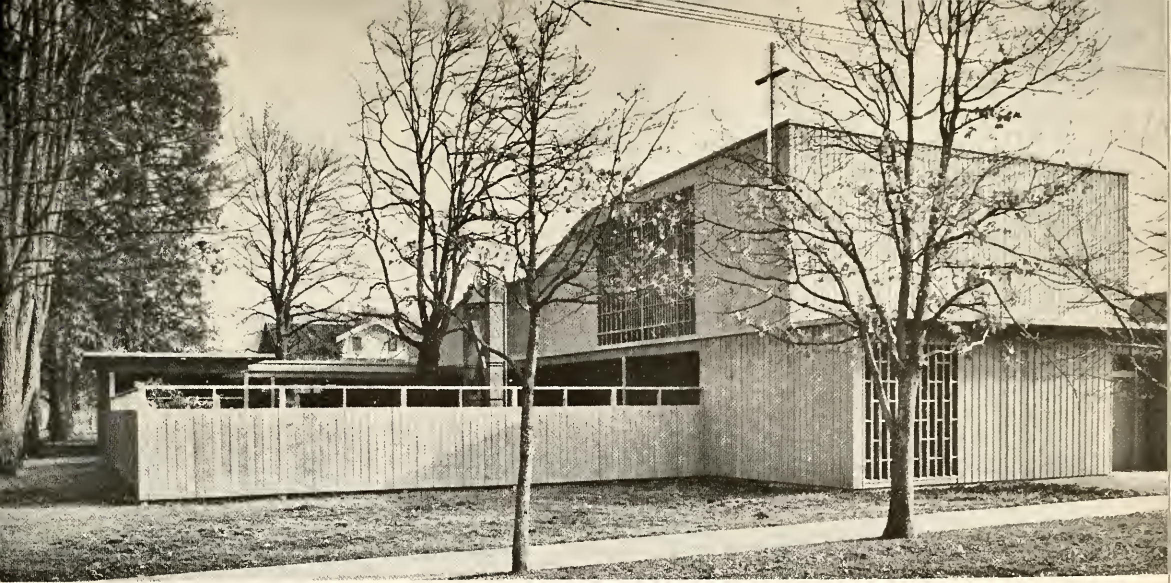


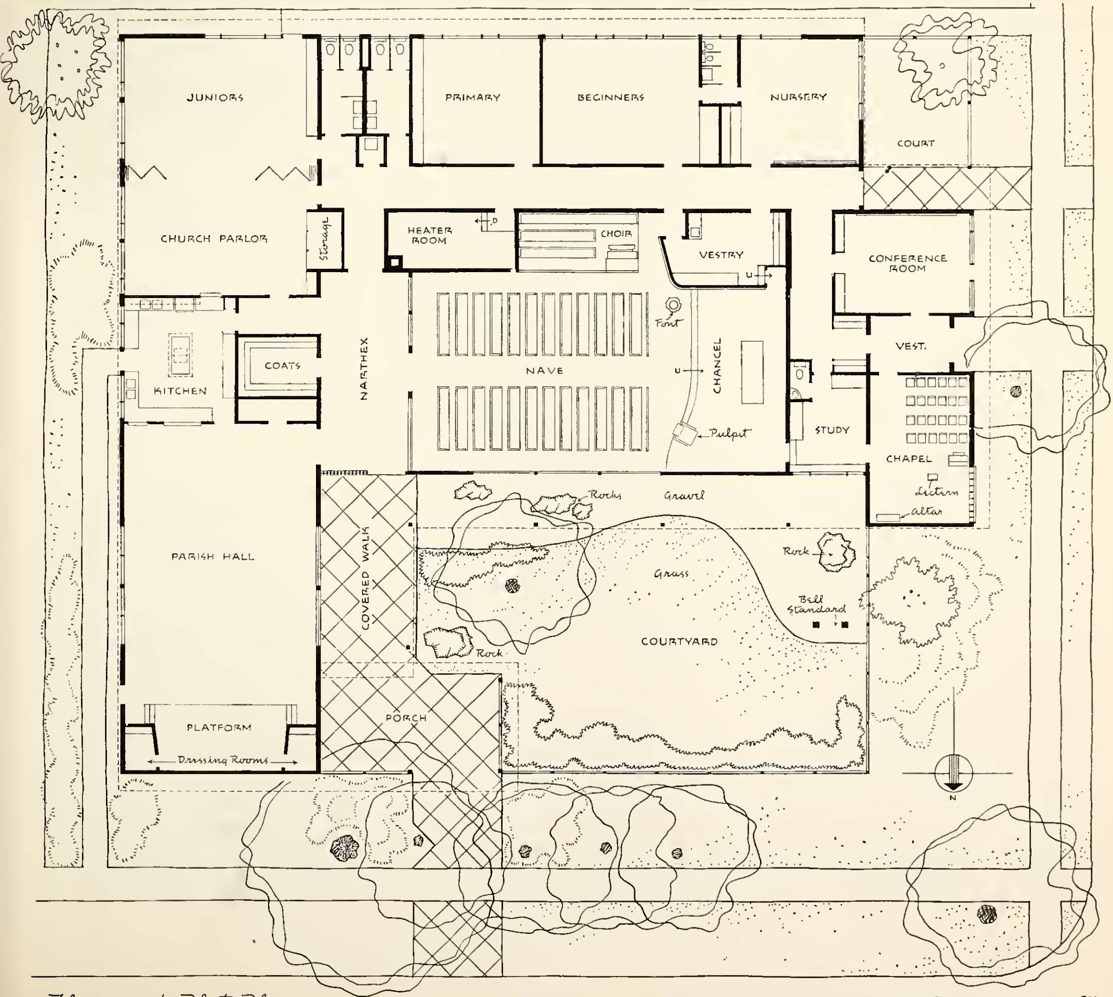


First Floor Plan

FIRST PRESBYTERIAN CHURCH, COTTAGE GROVE, OREGON

architect | Pietro Belluschi
general contractors | Alber Vik & Sons





Floor and Plot Plan

steam, either motor-operated or solenoid-operated sectionalizing valves; and, for circulating hot water, a separate circulating pump for each zone. In the opinion of this writer, the last would be the simplest for this particular case, since all the circulators could be concentrated in the heater room; dampers and steam valves, however, might be expected to take stations elsewhere in the system in order to best employ duct and piping facilities.

In any event, some form of supplementary heat appears to be justified for the rabbi's study, considering the isolation of both its physical location and its hours of use. Operating the main plant for such a comparatively tiny load is disproportionate and wasteful. A gas-steam radiator, a radiant-glass panel heater, or some similar unit should be satisfactory.

The view of the problem, as we now have it, suggests that either forced warm air or some arrangement of circulating hot water could best be adapted to this particular case. However, as we noted previously, the data and considerations examined are incomplete, and a firm decision must be deferred pending a detailed study.

An extremely interesting arrangement is illustrated by Pietro Belluschi's design for the First Presbyterian Church *(page 247)*.

Relative to our principles of church heating, the central location of the heater room is a strong assist to economy, since the heat-conveying channels, whatever they are, are both shortened and reduced in individual sizes.

From the standpoint of noise, the heating plant is subject to some suspicion because nothing but a partition separates the heater room from the church. This writer would be inclined to specify sound-absorbing material for all walls and the ceiling of that room, regardless of the type of heater selected.

Uniform heating in this church is not difficult to achieve, for the reasons pointed out in the Temple Beth Israel design. In fact, the presence of enclosing and heated structure on three sides makes uniform heating almost easier to obtain than not to obtain. Exactly how we would heat this church cannot be determined from the plan alone, as we need information concerning heights and materials, but the distribution problem is not complex.

Unit heaters probably could be used, at a saving, for the parish hall. The walls on each side of the proscenium offer possible grille positions, with the heaters set behind them. At the other end of the hall, the kitchen and storage walls also might provide grille areas. The arrangement could be similar to that shown in Figure 1.

From the standpoint of economy, these unit heaters should be separately fired, using gas-fuel and thermostatic control. Nothing would be saved by extending steam or hot water lines from the central heater.

The reduced need for heat-emitting equipment in the church, simplifies the problems of architectural harmony in proportion. The cost of a radiant floor seems unjustified in view of the warm walls on three sides, and we cannot decide from a plan alone if warm-air ducts are feasible. These eliminations bring us to the considerations of steam and hot water, the former seemingly impractical since the heater room is not below the floor level of the church, and condensate drainage would involve underfloor trenches, a receiving sump and pump. Therefore, hot water circulated by pumps appears at this moment to be the best solution of the problem. The arrangement of this church suggests that hot water equipment could be concealed or boldly positioned, as the architect might desire. Actually, the beauty of utility is everywhere illustrated by the human form and designers might ponder this fact with profit.

The principle of simplicity, as of economy, is assisted by the central location of the plant. Even if we were to use warm air ducts—perhaps locating them in a suitable ceiling, although the existence of such a ceiling is merely speculative—all zone dampers might be contained in the heater room. A similar concentration of controls for either steam or hot water is equally practical and indicated, each being actuated by a thermostat in the area served.

These discussions should emphasize that the principles of church heating are not complex in either idea or application. In fact, we can summarize each in a single word:

Economy	Silence
Uniformity	Beauty
Simplicity	

Violations result when we are guilty of superficial or wishful thinking.

Warm-Air Heating and Structure

BY WILLIAM J. McGUINNESS*

relative merits of heating systems

Proponents of various methods of heating have long proclaimed the advantages of their favorite systems. The choice of a method is frequently dictated by the occupancy or by the type of structure; conversely, the structure may have to be adapted to the kind of heating chosen. This is particularly true in the schemes under discussion. Steam, hot water, and warm air have all lived together long enough to have established the good qualities for which they are selected. A system may be ideal for the building it serves, but there is not likely to be an "ideal" system to replace all others. The improvement in controls, insulation, and distribution of heat have assured greater comfort in recent years. Good solutions have often been found in the combination of two or more systems; for example, the split system in winter air conditioning. In this system the radiators make up the heat loss at the outside walls while the humidity, cleanliness, motion of the air, and sometimes part of the heat load, are the responsibility of the ducted air.

the problem of heating a house

As progress was made in heating houses, it was found that gravity hot water offered some advantages over steam and that when forced hot water was developed it was a further improvement. Similarly, well distributed forced warm air is better than gravity warm air or a pipeless furnace. The better systems were usually a little more expensive and all had minor disadvantages which partly offset their excellence. Many of these problems were nearing a solution when we acquired a new kind of house and a new kind of heating system. The modern house and radiant heating arrived at about the same time. It is very easy to assume that they complement each other and that radiant heating is *the* solution to the heating problem of a modern house; indeed, this is largely true. A literal interpretation of this statement, however, will do little to improve further the heating of modern houses and the comfort of their occupants. Firstly, there are several kinds of radiant heating. The choice between floor and ceiling as a location for the heating panel involves a good deal of discussion of their relative advantages and disadvantages. Secondly, the use of forced warm air instead of forced hot water changes quite radically the nature of the heating panel. Generally, it makes possible a panel of smaller thermal capacity and consequently a faster response. The use of air permits the combination of partial air conditioning and radiant heating; this union, looked upon by many as a distinct advantage, is a characteristic of most of the systems described herein.

the case for warm-air radiant heating

In the short period during which radiant heating has enjoyed such an increase in popularity, forced hot water has been the medium chosen in a great majority of cases. Strangely enough, in the very beginning warm air was the favored method. The Romans and the ancient Koreans both used this system. Of course, the warm air consisted of the products of combustion, better known as flue gas or smoke, and a few disadvantages were apparent. Soot collecting in the passages and leaking through to the living space was hardly desirable. Slightly more serious was the appearance in the room of flame from the fire or the presence of poisonous carbon monoxide. The use of masonry in houses minimized some of these problems which would be much more serious in our wood residences. We have long since put our fire on the other side of a metal division and warmed air to be passed in back of ceilings or floors. One new system takes the added precaution of producing hot water first and then warm air by passing it over a convector. Recently, warm-air radiant heating has had a greatly increased use. It avoids the possible trouble of water leakage within the structure and possible freeze-ups if the house is cold and unoccupied. Unlike hot water pipes which must be imbedded in the radiating surface, warm air may pass on the other side of a thin surface. Heat is faster in arriving and there is less overshoot when heat is no longer needed—a most important factor in solar houses where the sun takes over quickly and calls for the heating system to be shut down completely and at once. Outdoor anticipating controls often needed in hot water radiant systems can generally be eliminated at considerable saving in expense. It might be assumed that some danger would attach to the method of passing warm air through house cavities, especially in wood structures which might catch fire at excessive air temperatures. The National Board of Fire Underwriters has already formulated regulations about this. When air comes directly from a warm-air furnace, an air-temperature limit control at the bonnet is mandatory to prevent air from circulating at a temperature exceeding 200 F. Also, the air passages in the structure must be wholly noncombustible or have a low flame-spread classification. When a converter is used to produce warm air from hot water or steam, the building passages may be built of nothing more combustible than 1-inch boards. The fire hazard of merely creating open spaces through the house is generally minimized by placing closeable dampers controlled by fusible links at the strategic control points. Federal Housing Administration has

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**Professor of Architecture, Pratt Institute, Brooklyn, New York. Illustrated by Raniero Corbelletti.*

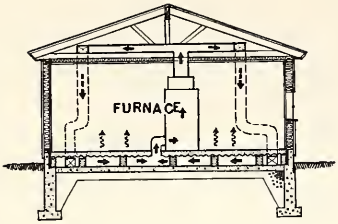
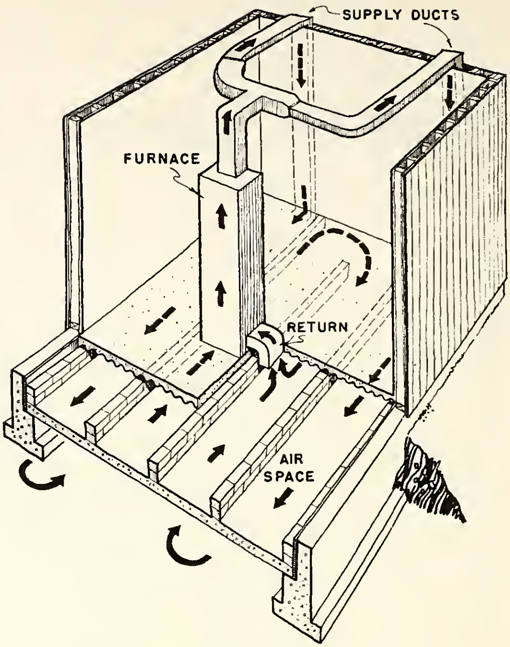


Figure 1a—an early warm-air floor panel system with no convection. Architects for a housing development using this heating method were Mellenbrook, Foley & Scott, Berea, Ohio.



been very watchful of this new system and has approved for mortgage guarantee only those installations that are safe as well as effective.

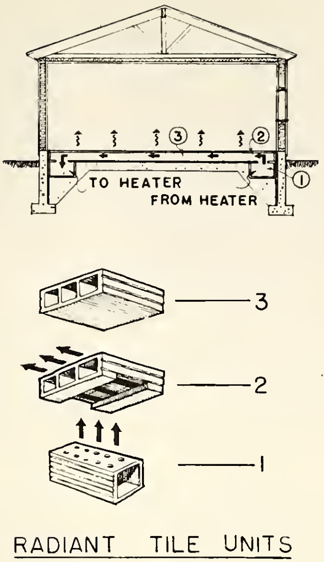
Probably the greatest advantage of all is the combination of the good qualities of radiant heat and winter air conditioning, facilitating humidification, filtration, and air-motion control. This undoubtedly can be extended to summer air conditioning. The cooling of room surfaces would produce radiant cooling to combine satisfactorily with a slightly reduced air temperature. The problem of condensation on the cooled walls can be solved by dehumidification provided that the house is kept closed.

radiant floor systems

An early method of warm-air radiant heating was described in February 1948, PROGRESSIVE ARCHITECTURE. Designers of this system which was installed at Berea, Ohio, were Architects Mellenbrook, Foley & Scott *(see Figure 1a)*. A warm-air furnace delivers air to a duct system in the attic space. These ducts down-feed through convenient stud partitions to seven or more starting points of the underfloor chambers. The air is first passed along the perimeter in these underfloor spaces which finally terminate at the furnace return duct; the slab is kept to a minimum of three inches above the air space. This would seem to be almost as slow in its response as a radiant hot water slab, but as the houses are of conventional design and without large glass areas, a slab of some thermal stability is satisfactory. The attic ducts need to be well wrapped to prevent excessive heat loss in that cold area. A floor of similar design but with an underground feed is shown *(see Figure 1b)*. This system uses hollow terra cotta block served by perforated terra cotta headers and square terra cotta ducts for supply and return. The ¾-inch tile web between air and room assures fast response and much of the heat loss from the feeder ducts is effective because of their position under the floor. The blocks make a finished tile-floor appearance and can be used without additional floor finish, which is an advantage because heavy carpeting will retard to some extent the effectiveness of a floor slab. In these and other floor systems using air, it is quite apparent that the floor will be dry and warm at all points.

floor systems that add convection

A scheme that includes baseboard grilles on exterior walls is shown *(see Figure 2)*. In this and other systems having air outlets near the exterior walls, the heat distribution is very good. Besides keeping the floor uniformly warm, additional heat in the form of warm air is introduced at the outside walls where it is most needed. The designers of conventional warm-air systems (not radiant) have taken a page from this book and are now tending toward the placing of outlet grilles on exterior walls instead of picking up the cold air at these points. The system illustrated in Figure 2 utilizes a new form well adapted to floor radiant heat. Twelve-inch square metal pans touch the concrete below on only 8 percent of their area which can be easily waterproofed with small discs. The thin metal (26 gage) and 1½ inches of concrete above provide fast heat conductance. Air distribution is by underground trenches of concrete which start the air at various points along the perimeter of the house.



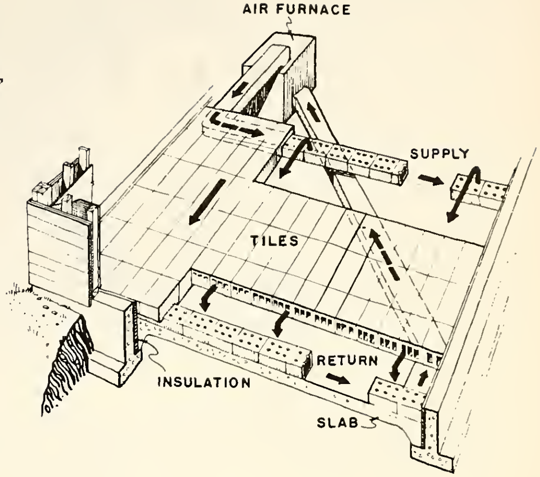


Figure 1b—a variation of the warm-air floor panel system without convection. Known as the RadianTile Heating System, this method was developed by Cannelton Sewer Pipe Company, Cannelton, Indiana.

Sheet metal baffles between the units create passages leading back to the furnace. Humidification and filtration are possible and the heating can be accelerated or retarded by opening or closing the grilles. Floor radiant systems have a disadvantage over ceiling installations because they are limited to temperatures of 85 F instead of 115 F, with correspondingly lower output. The addition of air grilles does a great deal to supplement the lower output and makes them comparable with ceiling radiant panels.

the popularity of perimeter heating

According to officials of the Federal Housing Administration, the use of perimeter heating has increased to almost equal that of conventional systems in some parts of the country. This system is ideally suited to the small house on a concrete slab. Research summarized in BMS 103 of the National Bureau of Standards states that the heat loss through the center of the concrete slab in a small house is negligible compared to the loss around the perimeter. It is obvious that if this loss is counteracted the floor temperatures around the outside walls will increase. If warm air can be discharged around the base it will aid in warming the exterior walls and produce a feeling of comfort *(this scheme is illustrated in Figure 3)*. The National Warm Air Heating and Air Conditioning Association, in its Bulletin No. 4, has summarized the details of installation and design for perimeter heating. The unheated middle of the floor slab on the ground must be very well insulated against loss to the ground which would reduce its temperature. It is also vital that the ground below this or any slab on the ground be kept perfectly dry; dampness greatly accelerates the heat loss to the ground and reduces the slab temperatures. An air furnace furnishes a down-feed supply to the radial ducts. Grilles supplied from the perimeter ducts discharge air directly into the room. There is a single return to the air furnace in a central location near the furnace room. A system of short return ducts exhausting from all the rooms will improve air distribution. The plan of delivering warm air directly into the floor slab and returning the air near the ceiling, or in short ducts in the attic space, is better for economy than delivering

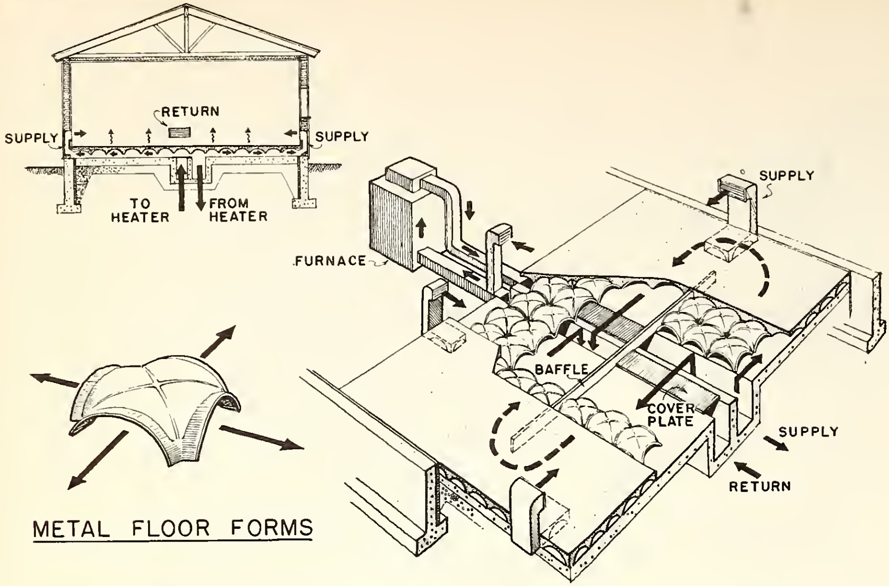


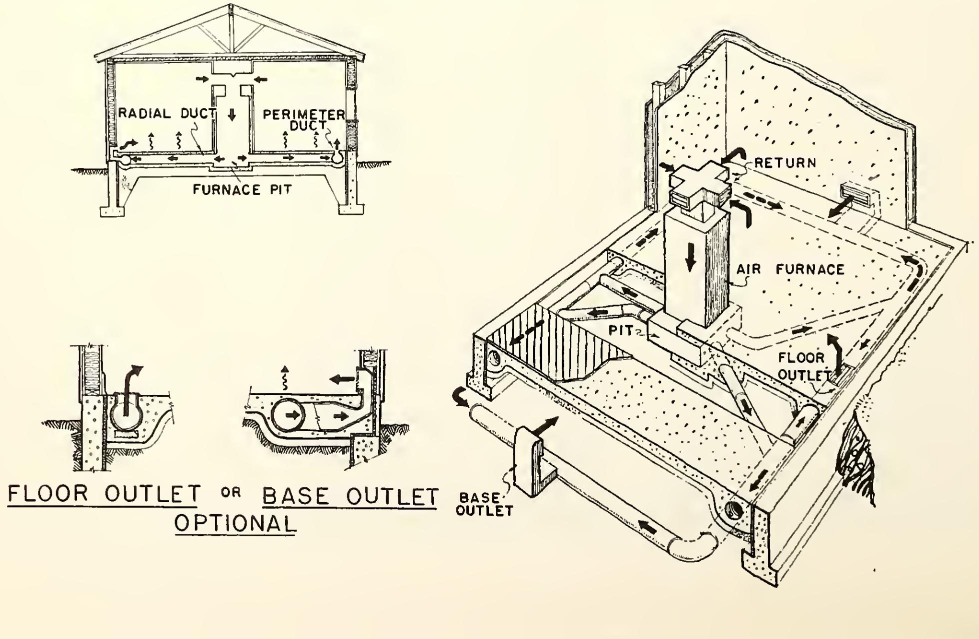
Figure 2—combination of radiant floor panels and warm air introduced into the room. The metal floor forms are manufactured by the Airfloor Company of California, Los Angeles.

warm air through attic ducts as in some other systems. There is a greater heat loss from the hotter supply air than there is from the cooler return air.

air baseboard replaces the grille

The general distribution of warm air in the perimeter system or in the system illustrated in Figure 2 can be further improved by the use of a new wall base air distributor. It is of small cross section, much smaller than the base used in hot water baseboard heating and, while no bigger than conventional wood base, it distributes warm air to heat all exterior walls. Screws along the length of the base adjust the opening at the top of the base, resulting in uniform air delivery along the wall. The top opening is partly closed in the vicinity of connecting ducts to divert the air to more remote spots. It reverses the usual downflow of cold air at exterior walls and is most useful under large glass areas or picture windows. It serves

Figure 3—perimeter heating combining warm-air convection and some radiant effect at the outside walls.



not only as an auxiliary in warm-air radiant floor systems but can be used in conventional forced warm-air designs to carry out the new idea of introducing warm air at the outside walls instead of interior walls. Because of the difficulty of passing air around the corner connections of the base, the ducts must connect at the middle of a length of base and each exterior wall length must be supplied by its own duct. This involves somewhat more duct work than is used in a normal forced warm-air system. *(Figure 4 illustrates the application of this new unit.)*

Intermediate floors that heat two stories

The integration of structural, self-supporting floors of noncombustible material with heating units is shown *(see Figures 5a and 5b)*. In both of these cases, the structural slab heats the story above and the basement below, and in each one warm air is admitted through slots or baseboard elements along the outside walls. Figure 5a illustrates the use of steel cellular panels in the "Ideal Home" of the 1950 Detroit Builders' show. The warm air flows from the center of the house toward the outside walls, which is a reversal of the usual procedure; however, the effect of the cooling of the air as it approaches the outside wall is undoubtedly offset by the introduction into the room of air from the panels through slots at the wall. This air compensates for the slow response through the concrete covering the panels and also makes the first story about equal in effect to the basement which is only heated by downward radiation; there is no convection in the basement. The bottoms of these metal panels are left exposed and painted. Some individual rooms in this house are heated by small electric radiant panels; however, their cost of operation is somewhat excessive. On one or two other jobs recently, engineers have adapted the metal floor panels of several manufacturers for a similar purpose. This is a new use for this type of material and these are the first applications of the principle. Rapid developments can probably be expected.

The system shown in Figure 5b is much the same, but uses hollow structural concrete floor panels. Here again, the warm air is all discharged into the first story through adjustable baseboard grilles. Air may also be introduced into the basement through similar adjustable elements, thus balancing the heating to suit the heat losses of the two stories. The same material has also been used as a closed radiant system by circulating the air through the open passages and returning it to the furnace. The split system, however, which admits air to the rooms has proven to be much superior because

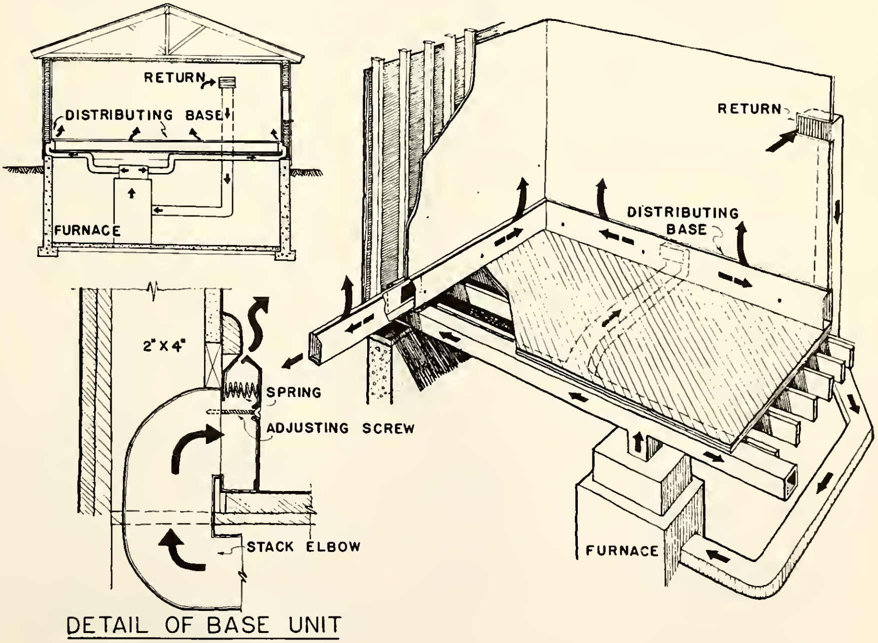
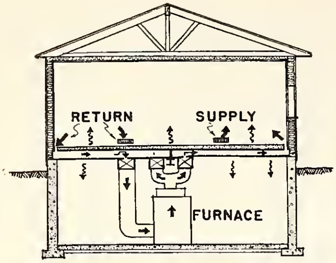
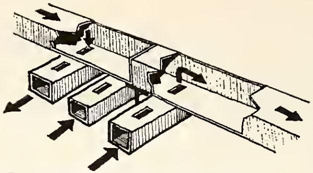
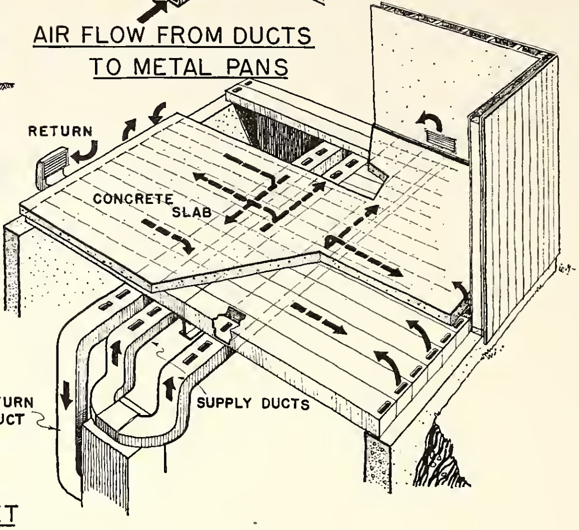


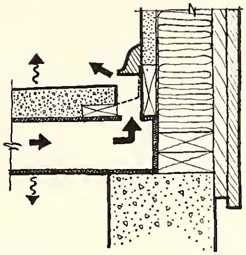
Figure 4—air distributing base for use with systems combining radiant heating and convection, perimeter heating, and conventional warm air systems. Brandes Company, Madison, Wisconsin, is the manufacturer of this base.



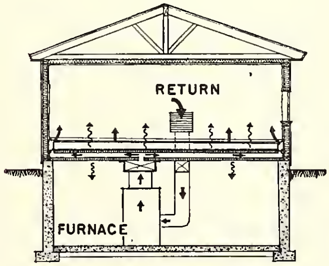


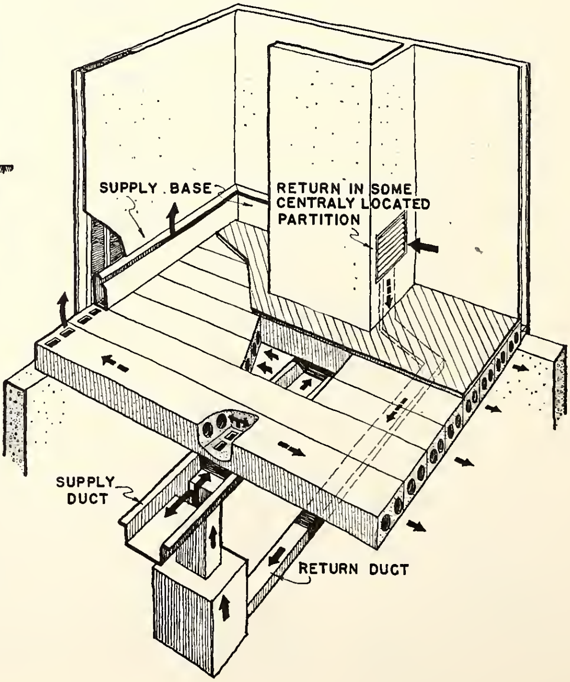
AIR FLOW FROM DUCTS TO METAL PANS

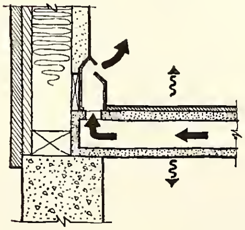




DETAIL OF BASE OUTLET







DETAIL OF BASE SUPPLY

Figure 5a, acrosspage above—this system which combines a radiant slab and convective air serves stories both above and below the slab. The cellular steel panels in this illustration are a product of the Detroit Steel Products Company.

Figure 5b, acrosspage below—hollow, structural, concrete floor panels are integrated in this system which also combines a radiant slab and convective air to serve stories above and below slab. Panels are prefabricated by Flexicore, Incorporated, Dayton, Ohio.

of the possible adjustment. About 100 of these jobs have been installed. Further thinking on the base detail seems desirable.

hot water assures extra safety

A very simple and safe method which heats both stories of a two-story house radiantly and the basement by convection, uses a hot water boiler with very short connections to a convector-type converter to produce warm air *(see Figure 6)*. For this particular kind of installation serving a two-story and basement house, the warm air rises through an asbestos cement duct to the floor intermediate between the first and second stories; no fan is required. The joists of this floor are cross-furred on the ceiling below to permit flow in all directions. The returns consist of enclosed spaces in the outside walls located at intervals around the perimeter; other sections of wall are heavily insulated. When the walls are cold from low outside temperature or lack of sun the cold air in the return duct drops rapidly, pulling warm air across the ceiling in the direction of the receding cold air. When the return duct, so close to the outside temperature, senses the heat of the sun or a higher air temperature, the duct air does not drop so rapidly and warm air is not drawn across the ceiling. Thus, it is quite self-adjusting. The return air descends through the cellar, warms it, and ascends again through the supply duct. Fire-link controlled doors provide automatic fire-stopping in case of emergency and the structure should be permanently fire-stopped above the heating floor. In this system, air may pass over wood surfaces with the approval of the National Board of Fire Underwriters, because the hot water converter prevents the possibility of overheated air circulating through the house. This is one of the few air systems in which domestic hot water may be produced by coils at the source of heat which is the hot water boiler.

warm-air radiant ceiling panels

If warm air is to be used in a closed system to produce radiant panels, the ceiling is the best location unless convection air is also admitted to the room. The reason for this is that ceiling temperatures and outputs may be higher and that the ceiling is the more truly radiant surface. The National Warm Air Heating

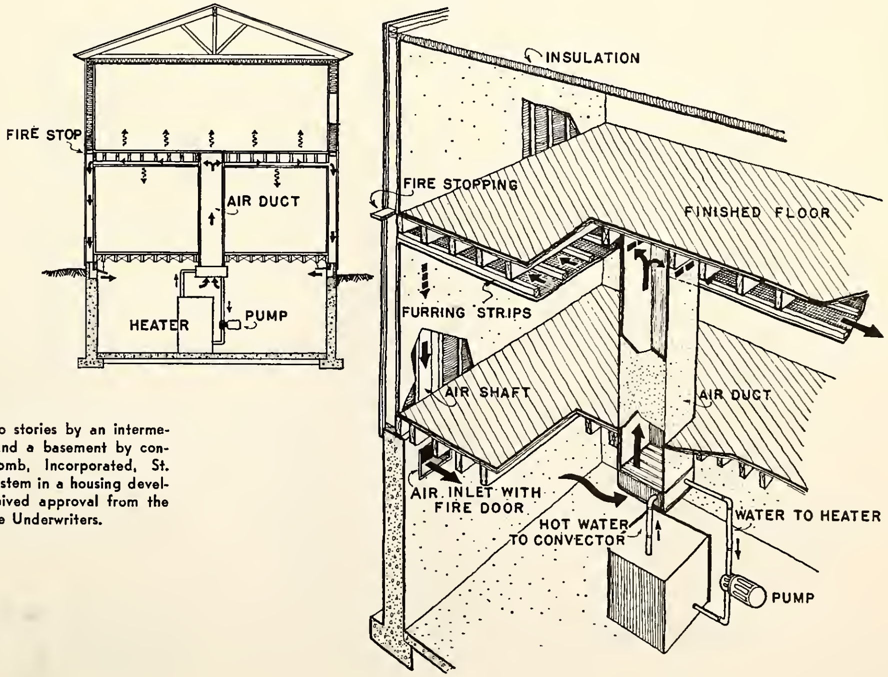


Figure 6—heating two stories by an intermediate radiant panel and a basement by convection. Scott-Newcomb, Incorporated, St. Louis, has used this system in a housing development and has received approval from the National Board of Fire Underwriters.

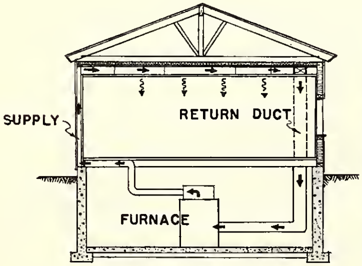
and Air Conditioning Association has established standards in the design of these systems in their Manual No. 7-A. One manufacturer's application of this principle is shown *(see Figure 7)*. Distribution ducts pass through the attic and should be well covered. The air passes between two ceilings in a chamber which must be noncombustible because of the use of an air furnace. These passages start at outside walls, are fed from above, and advance to the center of the house around baffles in the double ceiling. Down-flow returns collect the air and return it to the air furnace. The regular duct-type forced warm-air system has a temperature drop of about 100 degrees, but closed radiant systems have a drop of about 50 degrees with a corresponding need for the circulation of twice the quantity of air. Power cost for the fan may be expected to be a little higher.

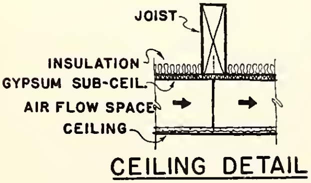
Research to compare the effects and response of panel and convection systems was carried out by Professors S. Konzo and R. W. Roose* on a special research residence. The performance of the two systems was almost identical and an excerpt from their report states: "If any single conclusion may be drawn, it would be that the response and performance of the two systems were surprisingly similar. The differences in the results obtained were not as large as the proponents of the two systems have claimed."

what's ahead?

If we are to credit the research of Konzo and Roose, there seems little reason for a struggle to break away completely from conventional warm-air methods in favor of radiant heat. The need for warmer surfaces within which to live is quite apparent, however, and radiant heating improves this condition greatly. Many people have felt that a combination of radiant heating and air conditioning might be a nearly perfect answer to the heating problems of many houses. Much of the data just reviewed points to the same conclusion. If we could select the best qualities in the systems described and put them together without too high a cost, we might dream up an ideal heating system. The ceiling and floors and, if possible, the walls, would be radiant panels of low output. Special elements would compensate for any excessive heat loss around the perimeter. Filtered and humidified air would make up the fluctuations above the steady low output of the radiant panels. The air would be introduced along exterior walls and particularly under large glass areas. Hot water boilers with converters would make it possible to use the structural passages without making them of fireproof materials and would also adapt well to the generation of domestic hot water. Where gravity permits the elimination of the fan, power could be saved and quietness achieved. Radiant surfaces would be of very low thermal capacity to facilitate fast pickup and shutdown. Finally, summer cooling might be accomplished by slightly cooling the room surfaces and cooling and dehumidifying the room air.

**Professors of Mechanical Engineering, University of Illinois.*





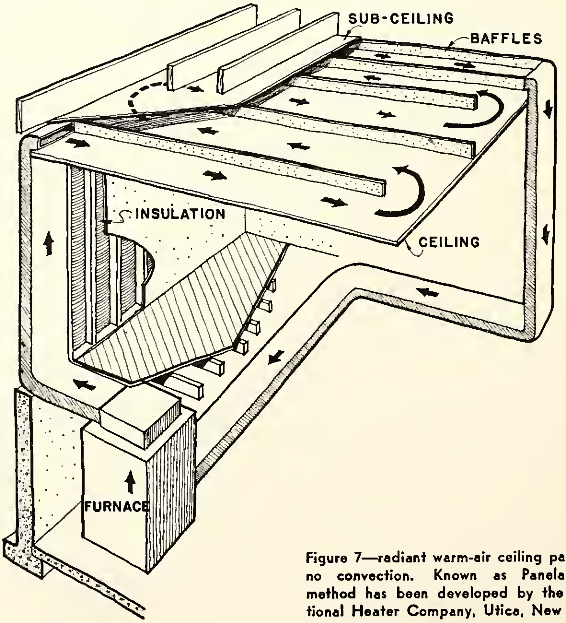


Figure 7—radiant warm-air ceiling panels with no convection. Known as Panelaire, this method has been developed by the International Heater Company, Utica, New York.

Crawl Space Perimeter Heating

BY WILLIAM J. McGUINNESS*

The problem of heating a basementless house built over a crawl space or on a slab has now been most satisfactorily solved by the warm-air heating industry. The solution provides for several systems, each of which assures uniform temperatures through the house, warm floors and walls, fast response, and a minimum of fluctuation. In spite of insulation, neither conventional radiator heating nor the usual forced warm-air system has been entirely satisfactory in producing uniform comfort in basementless houses. Baseboard, hot water, and warm-air radiant heating have solved the problem at somewhat greater expense. The new warm-air perimeter systems have proved their effectiveness and economy in this phase of heating. The customer has a number of variations to choose from; several of them have become extremely popular.

The National Warm Air Heating and Air Conditioning Association has been developing and cataloguing the best practices through its intensive research program and field testing laboratory. As recently as January 1952, its first complete manual of *Warm Air Perimeter Heating* appeared. Prior to this, however, thousands of installations had been successfully completed and operated with benefit of field advice. C. W. Nessell, who is in charge of the field laboratory, describes the performance of the new crawl-space plenum system as "quite spectacular." The perimeter-loop system for slab use was the first of these methods to be developed. It has wide acceptance and, according to the Federal Housing Administration, has taken its place in equal popularity with all of the older, conventional systems.

the perimeter group

Crawl-space plenum. A central down-flow furnace supplies warm air to a short-duct system below the floor, the ducts being only long enough to distribute the air well within the crawl space. Warm air then enters the rooms above through adjustable registers placed below the windows. Return air in this and all perimeter systems is collected at a grille in an interior wall and returned through a short duct to the furnace.

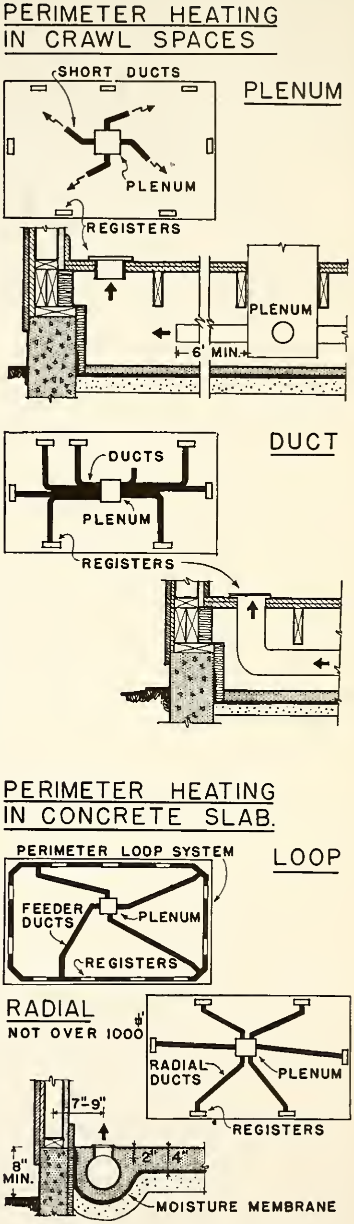
Crawl-space duct. Instead of using the crawl space as a plenum, ducts connect the down-flow furnace with the registers at the building perimeter. In small houses radial ducts can be used for this purpose, and in large houses an extended plenum or conventional trunk and branch system is suitable. One warm-air outlet in the crawl space warms it to at least the temperature of the rooms above.

Slab radial. This is the simplest method of connecting the furnace to the perimeter registers. The radial pipes are not quite as effective in warming the perimeter as the loop system and should not be used in houses exceeding 1000 square feet in area.

Slab loop. A perimeter loop is supplied by radial feeder ducts or pipes. Registers are fed from the perimeter loop. The pipe system creates a radiant floor which is particularly effective along the outside wall where the heat loss is greatest. (*Figure 1 illustrates the variations of perimeter heating.*)

Slab lateral. This method (*not illustrated*) consists of a down-flow furnace which supplies an underfloor distribution channel along the center of the house. Lateral pipes extending from the channel feed a perimeter air passage, all contained within the slab. From the perimeter pipe, a continuous baseboard slot or individual floor registers may be served. This approaches the principle of warm-air radiant heating and should have competent engineering design to be successful.

Figure 1—variations of perimeter systems in crawl spaces and slabs.
All drawings: Raniero Corbelletti



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* *Professor of Architecture, Pratt Institute, Brooklyn, N.Y.*

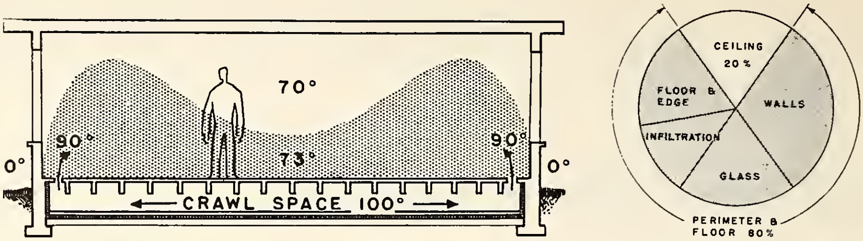

Figure 2—distribution of hourly heat loss from a small house on a concrete slab (right). *In perimeter systems, heat is applied at source of greatest heat loss* (left).

new concept of heating

Radiant heating has made us very conscious of the fact that the rate of radiant heat loss from the body to surrounding surfaces has a great influence on our comfort. In most heating systems developed recently, there has been an effort to have the occupant live within warmed surfaces of reasonably uniform temperature. Very cold surfaces must be eliminated if uniformly comfortable conditions are to be established. At the higher end of the scale, the source of heat in the form of warm air or radiators must operate at lower temperatures if we are to approach ideal conditions. It is now well known that the greater loss of heat through a slab or in a crawl-space house is along the perimeter rather than generally downward through the floor. Thus, the perimeter, walls, and glass are the coldest surfaces (*Figure 2*). The ceiling is somewhat warmed by the heated air that collects there. Now, if it is possible to warm these cool surfaces first and, in doing so, cool off the supply air so that it enters the room at a more agreeably low temperature, much of the above can be achieved. The method of doing this, obviously, is to pass warm air below the floor and then bathe the exterior walls and glass with the air from the registers. At the same time, the effect of infiltration which occurs at the outside walls is mitigated (*Figure 2*).

This is a new departure for the warm-air industry. For many years, inside walls have been used for supply ducts and registers and the cooled air collected at cold spots near the outside walls. Economy in the use of shorter ducts was one reason for this type of design. Another reason was the feeling that the warm air would be cooled unnecessarily in the outside walls without creating any warmer surfaces. As a result of this pactice, which still persists, the cold spots remained very cold. In many modern houses, the cool air is taken in a return grille or slot at the floor in front of large glass areas. This is intended to prevent the cool air from flowing back along the floor, but it is not always effective and the scheme usually results in a cold wall and window. Besides discomfort, much condensation results. The most recent trend even in conventional ducted systems, is to supply the air at the base of glass areas and this, of course, is the method used in all perimeter systems. Since there is no "cold" air but merely displaced air, it can be collected at any point remote from the supply registers. In perimeter systems, this is usually at a point or several points in the wall near the furnace.

crawl-space plenum

Prior to the introduction of perimeter heating, it was customary to supply heat within a room above a crawl space. Among the heat losses was the loss to the cold, drafty space below the room. Seldom was the insulation in the floor as effective as that in the walls or ceiling. Frequently, the crawl-space ventilators or windows were ill fitted or left open during the heating season. Result—cold floors and fuel waste. The crawl-space plenum system makes a room of this space and heats it with air at an average temperature of about 100F. A floor temperature of about 80F, and quite uniform, is thereby provided. This is within the range of usual floor temperatures in radiant heating and so the floor can be considered a truly radiant surface. The convection air entering the room is not much over 90F and far more moderate than the common 165F of conventional ducted systems. Temperature differentials between floor and ceiling in this and other perimeter systems can be kept within 4 to 7 degrees and, with careful balancing, the various rooms can be maintained at temperatures within 2 or 3 degrees.

The stub-duct system must have at least four ducts, each not less than six feet long (*Figure 3*). They must point to the corners of the house in order to reach the cold spots. The crawl space should not be more than about 18 inches deep below the joists; where a girder might block the flow of air emerging from a duct, the duct should be extended to a point past the girder. In L-shaped or other irregularly-shaped houses, the ducts will similarly have to be extended. It will be understood, however, that this system is not adaptable to large, rambling houses and is limited to houses having an hourly heat loss of not more than 100.000 Btu. Rapid shrinkage of floor joists may be expected and should be allowed for in the planning of moldings which can be reset. It is not unnatural and is merely an acceleration of the shrinkage that would take place in any case.

perimeter loop

This arrangement is ideal for houses on a concrete slab, and having an hourly Btu loss not exceeding 100,000. Houses with a loss of less than 60,000 may use the radial system in the slab. This kind of heating is a precise answer to the findings of the National Bureau of Standards in its early research on heat losses from slabs on the ground. Summarized in BMS 103, the Bureau's study showed the edge loss to be of greatest importance and dispelled the former theory that ground losses should be based upon the area between the house and the ground. In the case of a house above a crawl space, this edge loss does not affect the even distribution of floor temperatures which are quite uniform because of convection currents. In the case of a house built on a concrete slab, the edge tempera-

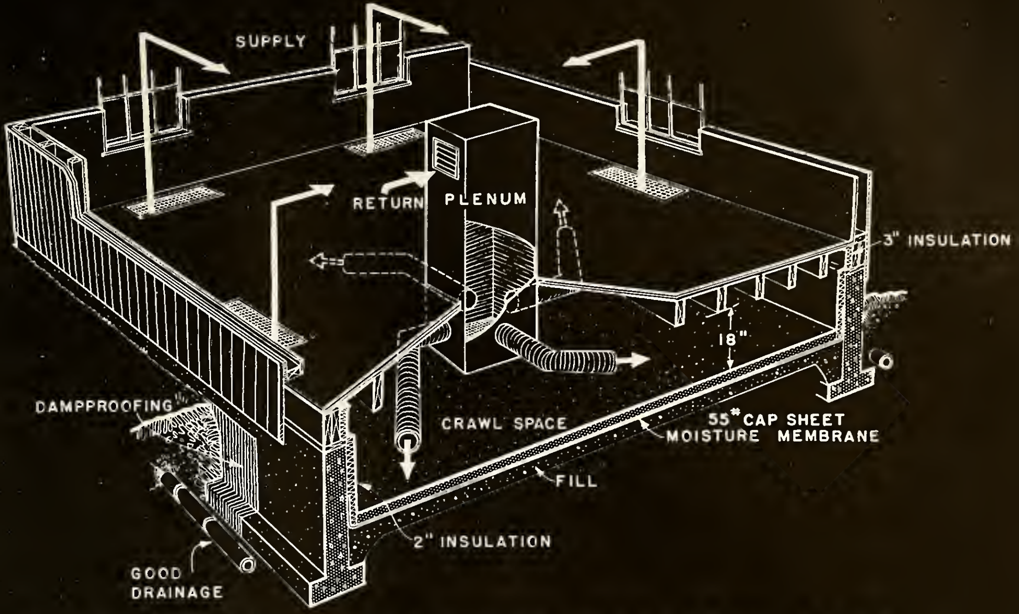

FIG. 3 SCHEMATIC VIEW OF HOUSE USING CRAWL SPACE PLENUM SYSTEM

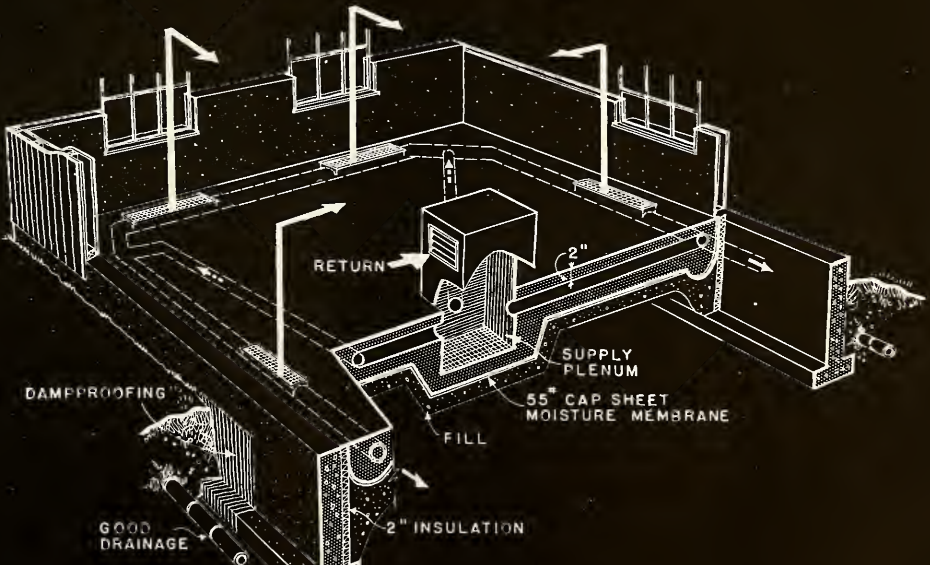

FIG. 4 SCHEMATIC VIEW OF HOUSE ON CONCRETE SLAB USING PERIMETER LOOP SYSTEM

tures are distinctly lower, even with good edge insulation. By warming the perimeter, these heat losses are offset. The combined system of radial feeders and perimeter loop forms a radiant slab which, while not quite as uniform in its action as the floor above a crawl space, produces uniform comfort at all points.

The ducts may be of galvanized sheet iron or of vitrified clay tile. They must be well fitted to prevent concrete from leaking into them during pouring. The light-metal ducts must be wired down to prevent them from floating while the concrete is cast. The clay tile will stay in place, but must be carefully grouted and calked to prevent leakage. Feeder ducts start at a level 5″ to 6″ below the floor surface and terminate about 2″ below, so that as the air cools it will heat the slab surface more efficiently. Conversely, the hotter air will not overheat the interior portions of the house where 6″ of concrete prevents speedy heat conduction from pipe to surface. The feeder ducts must terminate at the coldest locations, usually the corners of the house. Feeders should not supply more than about 15,000 Btu per hour, and registers not more than 8000. With these figures the preliminary arrangement can be sketched out at once. There should not be more than three registers between feeders, the distance between feeders should not exceed 35′, and no register should be more than 15′ from a feeder. Feeders must connect to perimeter ducts at right angles.

insulation and dampproofing

Under design conditions it is evident that a temperature of about 100F in the crawl space and 100F or more in the perimeter duct will cause a greater heat flow to the outside air than from a normal room temperature of 70F. By placing warm air close to the points of greatest exposure, the loss is accelerated. The usual edge factors cannot be used. In the case of a concrete slab, 1″ insulation passes 47 percent more heat than 2″ insulation. While 1″ is acceptable for performance, consideration of 2″ is recommended. The loss through 2″ may be computed on the basis of 65 Btu per hour for each foot of perimeter. Similar factors govern the selection of insulation for the walls of crawl spaces.

None of these systems must be used in damp ground. The greater density of moist earth increases the heat conduction and fuel bills will be excessive. This point cannot be emphasized too strongly. Drainage and the dampproofing of foundation walls are suggested and moisture barriers below slabs and crawl spaces are imperative. The material usually chosen is 55-lb. cap sheet, plastic-cemented together on 4″ laps. Under slabs, it must enclose the entire heating system and extend up to the floor surface (*Figure 4*). Crawl spaces are protected by a layer which turns up 6″ behind the insulation. In this case, the moisture barrier serves a double purpose. Its second use prevents the air from picking up ground moisture to subject the house to a humidity far in excess of proper limits. Crawl spaces must be airtight. Insulation must be of the waterproof type. Joists against the exterior sheathing must be insulated with 2″ or 3″ of batt-type insulation. The 2″ gravel cover over the barrier in the crawl space is optional, but the gravel base below barriers in all systems is necessary.

design and controls

The National Warm Air Heating and Air Conditioning Association provides design work sheets for all these systems, each of which differs slightly. Slab feeder and loop ducts range from 6″ diameters carrying 6000 Btu per hour to 8″ diameters carrying 15,000 Btu per hour. Hourly heat losses from rooms are computed in the usual way except that, in the case of crawl spaces, the area is computed as a room losing heat at a faster rate because of its high temperature.

Return air can be exhausted from closed rooms by grilles over the door (*Figure 5A*). Floor registers are preferred to wall registers. They should discharge on the room side of drapes and have a wide spread in both directions (*Figure 5B*). Return-air ducts must be sealed at the furnace, otherwise the air may be drawn in as combustion air by the furnace. Because most installations have furnaces at interior, and often closed, locations, it may be necessary to admit air from a vented attic for the sake of combustion (*Figure 5C*). In no case may the furnace room be used as a return plenum. Continuous operation is favored because it prevents stratification that might occur between widely separated periods of operation. The fan is turned on when bonnet temperatures reach 110F and off when the discharge temperature drops to 80F. This assures practically continuous operation at outdoor temperatures of 45F and lower. Arrangements are made so that the burner will operate at frequent cycles. At mid-design temperature, it will operate three minutes on and three off during the hour, thus changing to more "on" and less "off" as the outside temperature drops.

performance and economy

The already widespread acceptance and installation of these systems is sure proof of their value to satisfied owners, both in operation and in installation cost. They are light on critical materials and do not call for any unusual skills to design or install. Their compactness and adaptability to modern design is unquestioned.

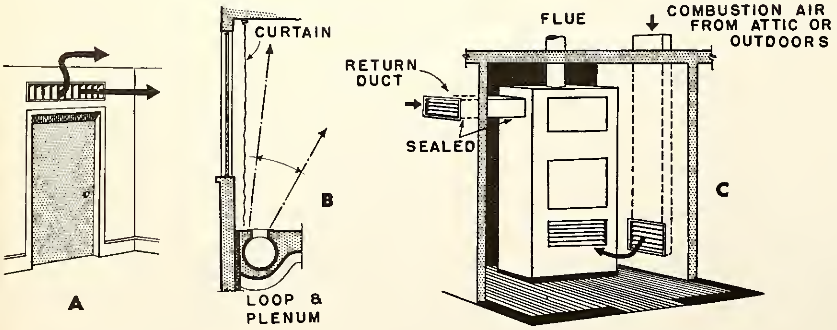

Figure 5—Various methods for control of air flow.

Advantages of residential baseboard heating

- *Lower walls are warmer*
- *Output largely radiant*
- *Less bulky than radiators*
- *Convection well distributed*
- *Offsets edge heat loss in slab*
- *Uniform air temperatures in rooms*
- *Reverses down-draft at window walls*
- *Can be used and installed before plastering*

Residential Baseboard Heating

BY WILLIAM J. McGUINNESS*

a new kind of heating

Within the past few years baseboard heating has made its appearance, has been the subject of complete research and testing, and has taken its place as a proven and accepted form of heating. Numerous manufacturers have developed units of many different shapes and forms, mostly to standardized ratings. Satisfactory installations have been made and employed throughout the nation with good success. Baseboard heating elements are normally installed along the exterior walls of the rooms in a house and connected either by supply and return branches off a one-pipe main or in a series-loop where the water flows through each unit in series and through short intermediate pipes which connect the units. In the latter case the heating elements form part of the main and save on piping.

There are two types of baseboards. One is the cast iron radiant type and the other is the fin type, consisting of copper tubing with copper or aluminum fins or of steel tubing with steel fins. Examples are illustrated in Figure 1. The term *radiant* applied to the cast iron is well chosen because the hot water stands against the inside of the front face of the unit, making it a radiating surface. One manufacturer makes a pressed steel unit with similar characteristics, which can also be classified as *radiant*. These cast iron (or steel) radiant heating units are further classified into two divisions, R and RC. R stands for radiant and RC for radiant convector. The word *convector* in this case does not put it into the fin and tube category, but indicates that there are cast iron fins and convector space in the cast iron units. The RC units are therefore of higher rating. Both R and RC are subdivided into low height and high height. In the fin type, one or two tubes (surrounded by fins) can be used with corresponding variation in output. While the radiant type has very direct and effective radiation from its front surface, the fin type, usually with an outside metal casing, has only a secondary radiative effect from the warmed casing. This difference is not great and either type may be used with equal effectiveness. All of these have sprung from the single tube and fin convectors used along walls in industrial heating for some years. In adapting this old principle to the new residential use, manufacturers have been vying with each other in developing the smallest and most compact designs possible within the required ratings. Another change from industrial practice is the choice of a heating medium. Many large industrial plants have vapor and vacuum steam systems available for heating. Both of these are capable of handling the difficult problem of removing the condensed steam in the form of water from long horizontal units. Few houses and apartments are so equipped and their one-pipe steam systems could not handle the condensate and would be subject to loud knocking. Hot water circulated by means of a pump is therefore the favored medium. Another very important characteristic makes the use of hot water desirable. At the steam temperature of 212 F, baseboard units have been found to leave very bad streaks on the wall due to speedy convection currents in the air. It is necessary to maintain a temperature of 200 F or less in order to avoid this difficulty. Water systems can be successfully operated on temperatures as low as 170 F.

adaptability for use in old houses

Those who favor baseboard heating and wish to install it in existing houses will find that it is readily adaptable. It can be installed in front of existing base although a better arrangement is to remove the base and set it against the plaster or a ⅛-inch asbestos board on the studs. The stud space directly behind the new units should be insulated with 4-inch mineral wool batts, otherwise there is a great loss of heating efficiency because of the proximity of the baseboard and the outdoors. In general, when switching to baseboard it will be found wise to insulate and utilize other heat savers such as storm sash and weatherstripping. If these precautions are not taken, it may prove difficult to limit the heating units to exterior walls. It might be necessary to place them on inside walls as well, which is not the best practice. In a one- or two-story house with basement, a one-pipe main can be used in the basement and supply and return branches run directly to first floor radiators. The second story units are served by supply and return risers concealed in the walls. Perhaps an easier scheme would be to use one pair of risers (supply and return) for each of the two floors, minimizing the cutting of walls. Each of these would serve a series loop, one for each floor. The only problem of cutting would be for an expansion loop, if needed, or for a door loop where the pipe must be interrupted and run below the saddle of any door in an exterior wall (see Figure 5).

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* *Professor of Architecture, Pratt Institute, Brooklyn, N.Y.*

use in new construction

Modern design and the advent of solar houses have tended to concentrate the windows of rooms on one wall only, usually the south. Sometimes there is an auxiliary high strip window on the north. Radiant heating has been a good solution to the heating of such houses. Baseboard, however, is now quite suitable for such conditions and offers many advantages. As an example, one such room, having a heat loss of 27,000 Btu per hour is now heated by radiant coils in the entire ceiling on minimum spacing. The south wall affords 30 feet and the north wall 22 feet for baseboard. If baseboard had been used, the required output per linear foot would be 27,000 divided by 52 or 520 Btu per hour per linear foot. Figure 1 shows a few units, selected at random from various manufacturers, but representing the range of capacities obtainable. It is evident that with 200 F water (which is quite standard) an RC High cast iron radiant element could be used with an output of 601 Btu per hour per linear foot. Only 45 feet of the walls would be used in this case to equal the room heat loss. The size of this unit is 1⅞ inches by 9⅞ inches. A more compact fin-type convector type (also Figure 1) may be used with an output of 525 Btu per hour per linear foot. This one measures 1½ inches by 8 inches. Baseboard would reverse the down draft which now occurs in this room on the north wall when the sun is out and on both walls at night. Its response to a call for heat is faster than that of most radiant systems. Modern design has also tended to minimize the size and even the use of ordinary base in rooms. The use of baseboard heating elements matched in the rest of the room with wood base or by the manufacturers matching metal casing which is obtainable, probably would not achieve the esthetic effect sought after in modern planning. There is no reason, however, why the heating base cannot be stopped at the end walls and not continued. Often these end walls are of brick or stone and need no base anyway. A number of the types of baseboard offered for sale to date have not been of the simplest or most attractive design. The critical selection by architects and the public is likely to correct this fault. Some new planning carries the window down as close as possible to the floor and the use of baseboard heaters would be a compromise in this scheme. These are a few of the difficulties in adapting the new system; however, by the co-operation of architects and manufacturers they can be overcome.

suitability to basementless houses

Research by the National Bureau of Standards in 1945, and by others since then, has established the extent of heat loss at the edge of the concrete slab of houses built on slabs resting on the ground. The loss at this perimeter location is relatively large, resulting in low temperatures at the floor near the wall, while at the center of the room the floor temperatures are about average. These things are caused by fast heat conduction through the walls from the slab, and the slowing down of heat loss through the center of the room to a section of earth with a large thermal content whose temperature has built up and become stabilized. Construction planners have partly compensated for this unbalanced heat loss by insulating vertically between the slab and the wall. Conventional radiators and forced warm air systems do not help much to correct the balance of this bad situation. Three other systems do. They are radiant heating, perimeter warm air heating (warm air in ducts under the room perimeter) and baseboard heating. Extensive tests during trial heating periods in 1948 at the University of

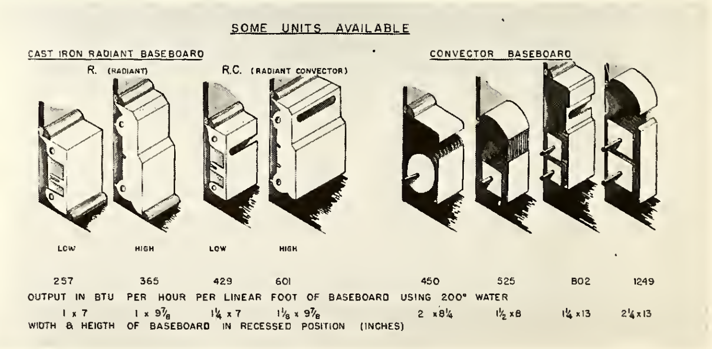
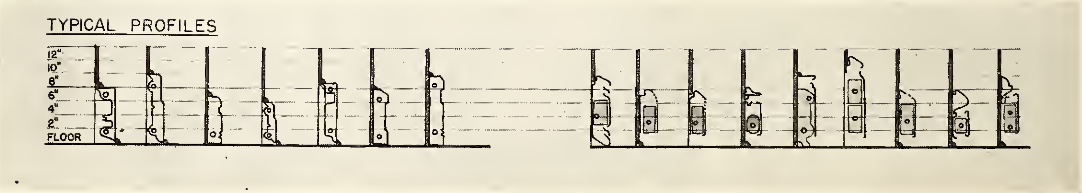


Figure 1.



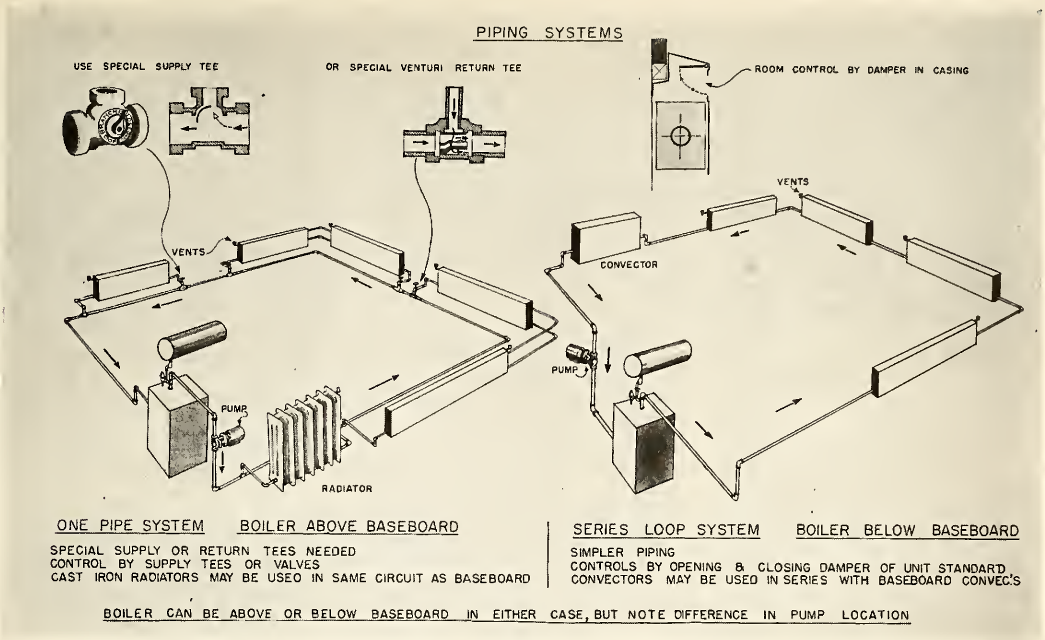

PIPING SYSTEMS
USE SPECIAL SUPPLY TEE
OR SPECIAL VENTURI RETURN TEE
ROOM CONTROL BY DAMPER IN CASING
VENTS
VENTS
CONVECTOR
PUMP
PUMP
RADIATOR
ONE PIPE SYSTEM
BOILER ABOVE BASEBOARD
SPECIAL SUPPLY OR RETURN TEES NEEDED
CONTROL BY SUPPLY TEES OR VALVES
CAST IRON RADIATORS MAY BE USED IN SAME CIRCUIT AS BASEBOARD
SERIES LOOP SYSTEM
BOILER BELOW BASEBOARD
SIMPLER PIPING
CONTROLS BY OPENING & CLOSING DAMPER OF UNIT STANDARD
CONVECTORS MAY BE USED IN SERIES WITH BASEBOARD CONVEC'S
BOILER CAN BE ABOVE OR BELOW BASEBOARD IN EITHER CASE, BUT NOTE DIFFERENCE IN PUMP LOCATION

Figure 2.

Illinois by Research Professors Weigel and Harris, sponsored by the Institute of Boiler and Radiator Manufacturers, have shown that baseboard heating is very effective in overcoming this difficulty in basementless houses. The following statement is made as part of the report of these tests. "The radiant baseboard is particularly adapted to maintaining comfortable floor slab temperatures in a basementless structure, as long, low units of this type cover a large percentage of outside exposure."

a variety of units are available

Cast iron baseboards have been quite standardized in output ratings and classified as R Low and R High and also as RC Low and RC High. Their dimensions vary slightly but typical measurements are given in Figure 1. Convector (sheet metal) type baseboards are not quite so well standardized and their rating will vary with the several manufacturers. In general they carry higher ratings although there is some overlap with the range of the cast iron units. Styles of several different manufacturers are shown in Figure 1. The smaller dimension or thickness out from the wall is from plaster to front edge of base when the base is recessed into the plaster, which is the most compact way of placing it. This is true for all except the first convector type shown which is not made in the recessed style. It is to be understood that the output will vary, depending on the water temperature. The usual temperature range is from 170 F to 215 F (in closed, pressure systems) with about a 50 percent variation in the ratings. Since it is impossible in this short treatment to give all ratings, those shown in Figure 1 are at 200 F which is the highest temperature possible that will not cause undue wall streaking. It is possible to quote or order the cast iron by "equivalent square feet of cast iron radiation," which relates to standard cast iron radiation. These figures are not given here. There is a growing tendency to rate equipment in Btu per hour.

piping can be simpler

One of the most novel features of baseboard is the possibility of using the series-loop type of piping. This is one of the circuits illustrated in Figure 2. As the baseboard units are so close together at their ends, it is quite logical to connect them together and allow the water to run through them as a single circuit. Between the units the pipe runs within an open metal base of matching pattern. This pipe is given some credit for heat emission in the general design. Indeed, the general concept is that a pipe is run around the house and fins placed on it to increase its output for as many feet as are required. Obviously no valves are possible for control of individual units. All convector type baseboards have a sheet metal cover and control can be accomplished by a damper which closes the top opening on the cover where no heat is desired. This system is quite effective. The layout saves on pipe and valves. Because the water at the first unit is hotter, it is normal to increase the middle third of the units by 7½ percent and the last third by 15 percent. When cast iron is used, the one-pipe system is suggested. This is identical with any one-pipe system using conventional radiators. In this case, special return fittings must be used to assure the proper diversion of the water to each element. Control valves at each baseboard or in each room make control possible. If an adjustable supply tee is used instead of a return tee, the valve can be omitted and the adjustment for the radiator made in the basement. This is a balancing operation, but in such a case room control is not possible without someone going downstairs.

elimination of air

Referring back to a conventional hot

water system using cast iron radiators, it will be recalled that air is eliminated by a small petcock at the top of each radiator. This is opened by hand and water pressure expels the air. Air has collected there because it is a high point in the system; each radiator is a trap for air. The cost of automatic vent valves for each radiator is usually prohibitive. The case of cast iron radiant baseboards connected in a one-pipe circuit is identical with the example just given and each unit will have to have a petcock vent which is checked once or twice a year. If two units are connected together longitudinally, so that air can flow along the top of both, one vent is sufficient. To accomplish this, it is necessary to join the top connections as well as the bottom. Any air released in the boiler, whether it is above or below the radiators, collects in the compression tank, the water level of which can be adjusted periodically. Where the series loop is used and the system consists essentially of one long horizontal pipe, an automatic vent valve can be installed anywhere; however, it is preferable to install it at a high point if one exists. Where such a system loops under a door, a manually operated or automatic vent must be placed in the run of pipe just ahead of such a loop. If the speed of the water in fin and tube systems is carefully adjusted by the use of a special pump and special pipe sizes, the designer may depend upon entraining the air and carrying it back to a central automatic vent in the return circuit near the boiler. In this case all vents are eliminated except at the one point indicated. Venting is most important, because if the system becomes air-bound, circulation is seriously impeded.

boiler and controls

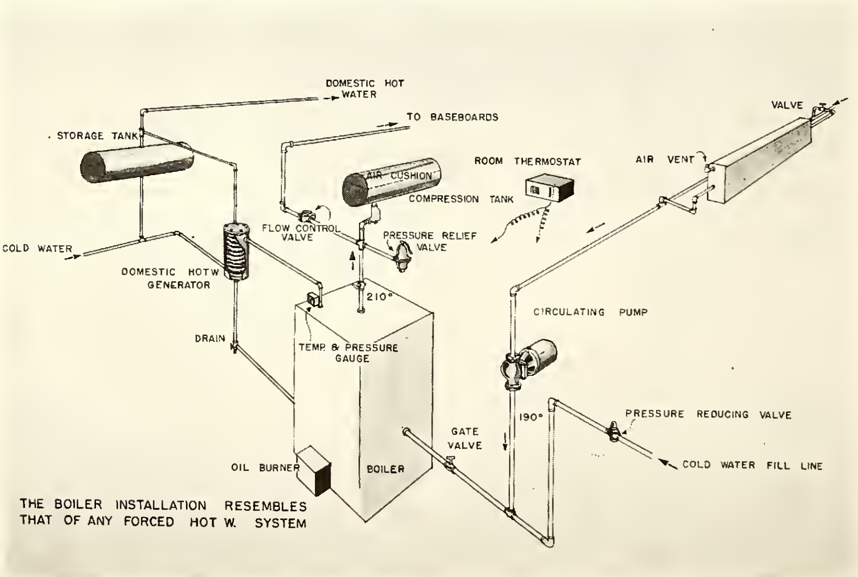
The closed system under pressure, with proper fill valves, relief valves, and an air cushion, is generally chosen for all forced hot water systems, whether for standard radiation or for baseboard heating. Figure 3 shows the piping and controls at a boiler and one baseboard unit in a typical system. If 200 F is chosen as a desirable average temperature in the baseboard, water is delivered at 210 F and received back at 190 F. This is a 20 degree drop which is quite usual in hot water systems. Whenever the boiler water drops below 210 F, the aquastat starts the oil burner. When the room thermostat calls for heat, the circulating pump and the oil burner are turned on simultaneously. When the room temperature rises to the degree called for, the thermostat turns off the circulating pump and the flow control valve closes against accidental circulation. If the system needs water, the pressure reducing valve opens and fills it. If the pressure within the piping and boiler accidentally becomes excessive, the pressure relief valve opens and relieves the situation. Small variations in the pressure are taken up in the air cushion of the compression tank.

design and layout

This might well be expressed in the sequence of operations.

1. Decide whether cast iron or convector units are most suitable as determined by the probable required output, the piping arrangements possible, and the architectural planning.
2. Choose between a one-pipe system and a series loop.
3. Compute hourly heat losses from each room or space in the usual way.
4. Measure and record the length available for baseboard on exterior walls in each room.

Figure 3.



THE BOILER INSTALLATION RESEMBLES THAT OF ANY FORCED HOT W. SYSTEM

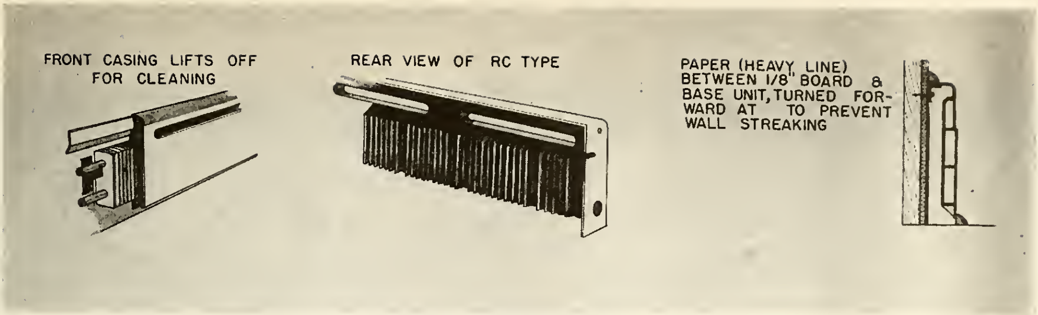


Figure 4: installation details

5. Compute the required output of the baseboard in each room in Btu per hour per linear foot if the entire available length of baseboard in each room is installed. (Heat loss per hour divided by the available length.)
6. Select the room with the maximum required output and choose the proper average water temperature and the length and type of baseboard required.
7. With the average water temperature established, select the length and type of baseboard needed in each room.
8. Make a scale diagram of the system, place all controls and measure the length of the piping and list the fittings in the longest circuit.
9. Establish the "equivalent total length" of the system and the gallons per minute that need to be circulated. The latter depends on total heat loss and temperature drop.
10. With the above information, select a pump, and size the piping in accord with established practice for hot water heating.

installation

In using cast iron an allowance for expansion of ⅛ inch must be made for each 10 feet of baseboard. Connections to the one-pipe main should preferably be by a swing joint, if threaded pipe is selected, or be long enough to permit some bending if sweat fittings are used. The expansion of copper or steel tubing is taken up in long pipe runs by using an expansion loop at one or two points in the length of any long run of the series loop. Door loops also serve to absorb expansion. Both of these are shown in Figure 5. In order to avoid wall streaking it is necessary, besides controlling the water temperature, to install sisal or other heavy paper behind all cast iron units and turn it forward ½ inch, covering it with a ½ inch quarter round molding. This diverts the air away from the wall and toward the room. Convector type units do not usually need this precaution. In their use, however, it is desirable to select a type in which the upper opening is on the front face of the casing and not on the top. The top opening makes for greater efficiency of flow, but also dirties the wall by direct upward currents. Convector types are mostly clear of the floor and are installed on hangers, a casing being hung in front of them later. The casing is also clear of the floor and a vacuum cleaner can be inserted below to the wall. The casing is usually removable for occasional cleaning of the fins. In the cast iron units, the R type often rests on the floor and is finished in front with a quarter round. The RC, however, is clear of the floor (like the fin-convector type), in order to induce air flow through the bottom.

appraisal of the method

Advantages:

1. Comfort is enhanced by the use of a heating medium lower in temperature than steam and most hot water systems.
2. Better uniformity of room air temperature both laterally and vertically.
3. Higher mean radiant of the lower half of the room (the portion of human occupancy).
4. Better for slab jobs than some other methods. Insures upward air flow at wide windows.
5. Does not interfere with drapes as radiators do.
6. Tests indicate good relative humidity.
7. Need not be removed for wall decoration like radiators.

Limitations:

1. The size of the base is larger than most modern wood base.
2. Alterations involving removal of sections of exterior wall are not easy.
3. Drains for water must be provided at the bottom of door loops.
4. In spite of the lower sections of wall being warmer, the general mean temperature of the room is no higher, because ceilings are colder.

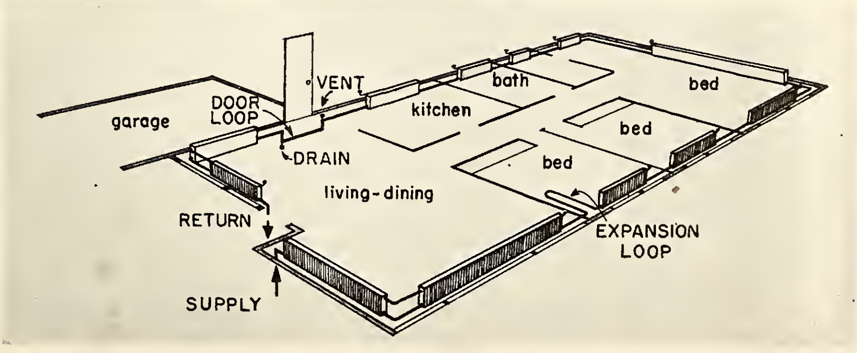
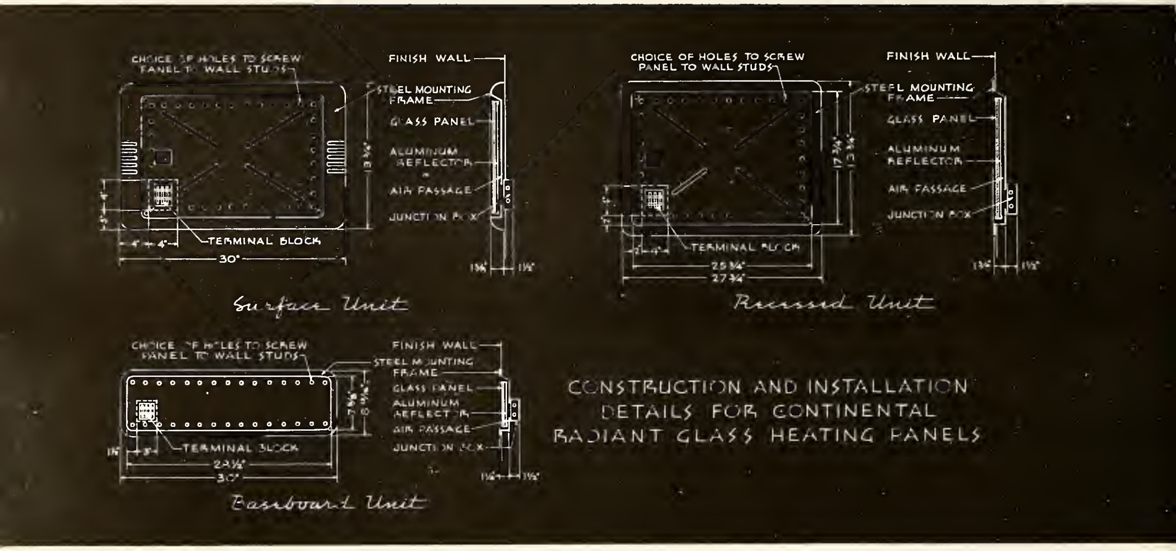


Figure 5.



CONSTRUCTION AND INSTALLATION DETAILS FOR CONTINENTAL RADIANT GLASS HEATING PANELS

Design Data for Radiant Glass-Panel Heating

BY WILLIAM ANDERSON*

Electricity not only provides the cleanest form of heat with the least effort, but also permits an efficiency obtainable by no other means. An architect or engineer must know, however, when to recommend electric heat and when not to. Although his clients may request this form of heating, many of their homes are unsuitable for such a system. If electric heating is installed in such a house, high operating costs may tend to jeopardize the architect's or engineer's reputation.

Of the many types of electric heaters now available, none is more efficient or more economical than the radiant-glass panel. Although widely used in France prior to World War II, this type of heating equipment was not introduced in the United States until 1948—when the Continental Radiant Glass Heating Corporation produced its first units.

The feasibility of installing radiant-glass heat in a home will be influenced by the amount of heat loss. The method of computing the heat loss is like that for any other type of heating system, except for that part of the loss due to air infiltration. If the crack method is used, standard figuring is permissible. If the air-change method is used, however, only one air change should be allotted instead of the customary larger amounts. It is possible to use this smaller volume, as excess air is not required for combustion and as radiant-glass heating does not dry out the air. The higher humidities that are obtained contribute substantially to the high degree of comfort that is possible.

The total heat loss for an individual room should be divided by 3415 in order to determine the number of kilowatts required for that area. Storm windows should not be considered when determining the installed kilowatt capacity; they should, however, be considered when computing the kilowatt-hour consumption. As a rule of thumb, a properly designed house will have about one panel per thousand cubic feet, plus one. A 7000 cubic-foot residence, for example, will usually require eight 1000 watt units.

Each of the Continental panels is composed of three primary components: (1) a tempered-lime-glass sheet with a fused-on aluminum element; (2) a reflector placed behind the glass plate; and (3) a frame. The reflector reduces the reverse heat loss of the panel so that all possible heat is emitted into the room. Holding the glass-reflector assembly, the frame can be surface-mounted or recessed in the wall.

Panels should be located under windows, and on exterior walls wherever possible. If recessed panels are desired, the openings should be braced during construction. A surface-mounted panel requires a 4" x 4" opening for the junction box located behind the reflector. Panel sizes vary as follows: baseboard units are rated at 450 watts and wall units are of both 625- and 1000-watt capacities. All are available in recessed or surface-mounted frames and in a range of 115, 208, 220, 230, and 245 volts.

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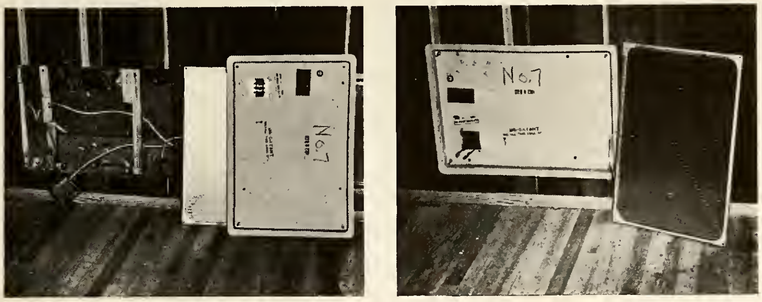
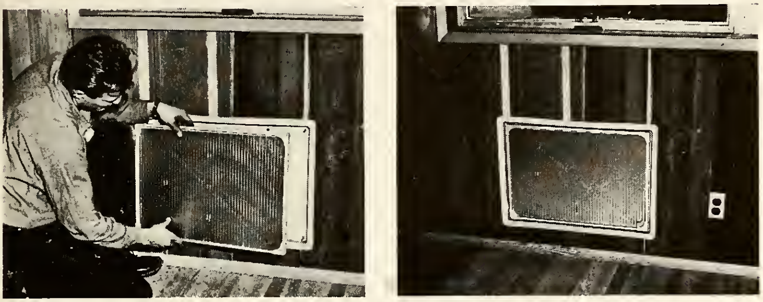
* *Consulting Engineer, New York, N. Y.*



Component parts of recessed, radiant-glass panel (far left) *before installation in wood-frame wall. Space must be provided for junction box located behind reflector. Steel mounting frame ready to receive glass panel* (left).



Workman placing glass panel of 230-volt, 1000-watt unit (far left). *Panels should be located under windows, and on exterior walls wherever possible* (left).

The 115-volt unit is primarily used where only one panel is desired for auxiliary heating; otherwise, the complete home should be wired for 230 volts. For ceiling installation, combination heating and lighting units are available in 750-watt capacities. Maintenance is not required for radiant-glass panels. Tests have shown that the reverse heat loss is about 15 Btu per hour or about 0.45% of a panel's output. Each room must have its own thermostat to prevent overheating and to provide individual room control.

The heat loss for the average house should not exceed 3 Btu per cubic foot per hour. To insure that this rate of loss is not exceeded, the following quantities of mineral wool insulation (or equal) are recommended: 4″ in the ceiling, 3⅝″ in the side walls, and 2″ under the floor. If a concrete floor slab is used, perimeter insulation is mandatory and a water-repellent membrane must be used under the slab. The foregoing specifications greatly reduce both the installed kilowatt capacity and the kilowatt-hour consumption.

To obtain the kilowatt-hour consumption, the FHA has devised a formula specifically for glass heating:

$$\text{KWH} = \frac{\text{Btu loss} \times \text{Degree days}}{\text{Temp. diff.} \times 200}$$

About 90% of the country enjoys electric rates that are economical for a properly installed electric heating system; utility rates of 2 cents per KWH are competitive with operating costs of other heating systems. The designer should consider the plus factors of lower building costs, interest and amortization charges, absence of maintenance, etc.

A typical home can be analyzed, to determine whether glass heat is feasible. Assume that a 20′ x 30′ bungalow with basement is located in New York City. The heat loss without insulation is about 63,700 Btu/hour and approximately 18½ kilowatts of electric heat are required. The yearly KWH is:

$$\text{KWH} = \frac{63{,}700 \times 5280 \text{ (Degree days)}}{70 \text{ (Temp. diff.)} \times 200} = 24{,}000$$

At 2 cents per KWH the cost amounts to $480.

With 4″ mineral wool insulation in the ceiling, the heat loss is reduced to about 37,240 Btu/hour so that 11 kilowatts (37,240/3415) of heat are needed. The total KWH will be 14,100 and at 2 cents per kilowatt hour will cost $282 per year. If 2″ insulation is placed under the floor and 3⅝″ insulation installed in the walls, the resulting heat loss is 24,000. The required number of panels is 7 kilowatts and the KWH estimate is 9000 which, at 2 cents, costs $180. This was computed without consideration of storm windows; if storm windows are to be used, 7 kilowatts should be installed. The KWH estimate now becomes 6800 which, at 2 cents, would cost $136. In this example, basement heat was not considered and only the 4800 cubic feet of living area was examined; 160 sq ft of window area was assumed.

Radiant Low Voltage Electric Heat

BY ALFRED H. ABERNATHY* AND DAVID R. SHEARER**

In approaching the problem of selecting floor or ceiling radiant heating for this small office building in Tennessee, the architect and engineer first considered its use, orientation, and surrounding topography. Where ground is relatively level and a concrete slab can be easily installed, these authors lean toward floor heat—especially in small office buildings, commercial buildings, churches or other structures with excessively high ceilings. Based on the findings of this case study, it is apparent that radiant low voltage electric heating operates quite satisfactorily and economically where the power rate is low and the installation is not too large.

A new type of low voltage radiant electric heat has been installed in the offices of Architect Alfred H. Abernethy, at Johnson City, Tennessee. Before the system was finally installed, Electrical Engineer David R. Shearer, who originated this method, collaborated with the architect for many weeks performing elaborate tests with both No. 9 and No. 12 steel wires in concrete and plaster panels to determine the correct spacing, pick-up, impedance, temperature curves, and other data for proper design. As there is no temperature drop through the coil itself, and as the coil reactance varies with the spacing and size of the wire as much as it does from ohmic resistance due to length, it was found that the calculations involved in the design were far more difficult than those for a water system. Ordinary tables of steel wire resistance could not be used for alternating current in steel coils of this type.

The system eventually developed consists of eleven coils of bare annealed steel wires embedded in the floor slab in the same way that pipes are used in a hot water radiant heating installation (see sketches of floor plan and section). Data on the coil schedule follows:

Drafting room (322 sq. ft.) : four coils at 130 ft. each; 520 lin. ft. of No. 9 (1570) steel wire; 17 watts per sq. ft.; 5.4 kw.

Office (184 sq. ft.) : two coils at 130 ft. each; 260 lin. ft. of No. 9 steel wire; 13 watts per sq. ft.; 2.4 kw.

Reception and storage (336 sq. ft.) : three coils at 130 ft. each; 390 lin. ft. of No. 9 steel wire; 12 watts per sq. ft.; 4.1 kw.

Conference (183 sq. ft.) : two coils at 130 ft. each; 260 lin. ft. of No. 9 steel wire; 15 watts per sq. ft.; 2.3 kw.

The coils, which also serve as reinforcement for the slab, are connected by brazed joints to bare copper feeders from the control board. Room temperatures are controlled by thermostats operating magnetic on-and-off switches connected to the circuits; voltage modulation is achieved by three interlocking, outdoor thermostats controlling three corresponding taps on a specially built dry type transformer. When the outside temperature reaches 72F, the current is automatically shut off. At temperatures ranging from 71 to 45F, the available voltage is 20 volts; from 45 to 20F, the tap is 30 volts; below 20F the tap is increased to 40 volts. A 15 kva transformer is served at 230 volts. Although the heating coils operate at a temperature of 130F, a test temperature of 200F was run through the coils without ill effect when the system was first installed. Temperatures of the concrete floor surfaces are maintained at 80F or less during operation. Transformer and control equipment demand little space in this building and are located in the storage room. The slab containing the heating coils is only 1½″ thick and rests on a 2½″ bed of vermiculite insulating concrete with standard edge insulation. The highest voltage used in the floor is only 40 volts, so there is no possibility of shock or burn, and as these coils are completely incased in concrete there is no deterioration. Tests have shown that there is a slight leakage between the runs of the embedded coils; however, as this also goes to heat, there is no loss.

The present kilowatt rate for TVA power available in Johnson City is:

Residential: first 50 kw, \$0.03; 150 kw, \$0.02; 200 kw, \$0.01; 1000 kw, \$0.004; and over 1000 kw, \$0.0075.

Commercial: first 150 kw, \$0.03; 350 kw, \$0.02; 1250 kw, \$0.01; and over 1250 kw, \$0.008.

There are no demand charges for residential installations; however, for over 10 kw, small commercial consumers pay \$1 per kw; medium and maximum consumers pay \$1 from the start. In addition, there is a 10 percent surcharge for all commercial installations.

During the heating season, the electric bill for this building has averaged \$32 per month. As approximately one-third of the current was consumed in lighting and blueprinting, a net cost of \$22 was required to heat the 1200 sq. ft. area. The capital investment, compared with an oil fired hot water radiant job, is about one-third, since the chimney, additional space for boiler, and so on, were eliminated. As there is no demand rate for non-commercial property, the monthly consumption for a house of this floor area would be considerably less.

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* *Architect, Johnson City, Tennessee*

** *Electrical Engineer, Johnson City, Tennessee*

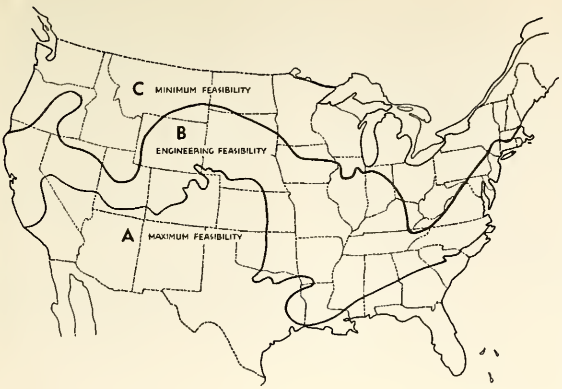

Figure 1—feasibility zones for solar house heating. Heat requirements can be supplied in zone A—by solar radiation collection devices without expensive enginering; B—by solar radiation collection devices and careful engineering design; C—full heat requirements cannot be supplied by even the most elaborate solar heating system.

This discussion, an analysis of some of the architectural and engineering problems related to the design of a successful solar-heating system for a house in the vicinity of New York City, was originally prepared as a thesis for a Bachelor of Architecture degree at Pratt Institute. In editing his manuscript for publication, it was necessary for the author to reduce its text and to eliminate a number of his substantiating charts, diagrams and tables.

Design Data for a Solar House

BY GEORGE S. SHARON

The dream of having a home fully heated by the sun has at last become a reality. Several houses in the Boston area now contain collectors (each composed of a black-painted metal plate, an air space, and two panes of glass) which successfully gather solar energy and efficiently store it in either water or chemicals ready for release when needed for house heating.

regional feasibility

Before the design of a solar house can be considered, it is necessary to know whether it can be sustained by its regional location. (*Figure 1, based on the available solar radiation and degree days, indicates the various regional suitabilities for solar heating.)*

architectural considerations

In a solar design, an architect is faced with definite restrictions imposed by the heating system. Because it is necessary to receive the maximum available solar energy, south orientation of the collector is mandatory. High ceilings, over-use of glass, large exterior wall perimeters, and many exterior wall openings are sources of excessive heat loss and should be avoided. Glass areas should have drapes or screens which can be drawn during the evening and inclement weather, and structural areas should be well insulated.

A lampblack collector plate has the highest absorptivity of the known pigments. Because black is not appropriate for a home, a better color scheme is desirable to reduce the somberness created by the large collector surface. Medium green (trim color) may be used as a satisfactory substitute.

In order to prevent the collector from being cracked by overheating during the summer months, an overhang, awning, screen, shade, or a whitewashing of the glass may be considered as an adequate safeguard.

collector placement

The basic positions of the collector are on the roof and on the ground. Either of these positions may be used with a level or sloped site. A design for a level site may be considered as a universal solution, since no special land contours are required, at the same time, it is easily adaptable to a sloped site.

roof placement

One scheme for a level site has been the placement of the collector on the roof and the treatment of the collector and living areas as one complete structural development (*Figure 2*). In such a solution, the length of the house is governed by the length of the collector. A collector requiring an area of 720 sq. ft. and a 10′ height has to be 72′ long; as a result, there is a loss of human scale and a complete domination of the living areas by the collector. Other disadvantages of such a design are the long, thin plan, large exterior wall perimeter, and the low proportion of usable volume. The design, however, has the advantages of a large, unobstructed, heat gain through a dominant south orientation, good insulation given to the ceiling and collector, and simple construction. Using the elongated plan, whose façade incorporates the heat collector, other design forms are possible (*Figure 3*). Human scale and collector subordination may be achieved in the elongated plan by splitting the collector (*Figure 4).* In the vicinity of New York City, a 5′-high collector casts a maximum horizontal shadow of 17.7′; thus the split collector is architecturally feasible (*In scheme "A" of Figure 4, the exposed backside of the collector creates a heat-loss problem. Schemes "B" and "C" reduce heat loss through the backside by incorporating attics, but have the disadvantages of being structurally and esthetically more complex.)*

The roof itself offers a large area for solar collection. A roof pitched 40° has a favorable solar tilt and sheds snow well (*Figure 5*). This scheme offers a compact plan, small exterior wall perimeter, and good insulation to the ceiling and collector. The steep roof, however, may be esthetically questionable.

ground placement

The placement of the collector on the ground results in many compromises. Although south orientation is mandatory for the collector and desirable for the living areas, it is difficult to satisfy both conditions simultaneously. By orientating the living areas other than south, the south wall itself may become the

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Figure 1: Dr. P. A. Siple, "Space Heating with Solar Energy", Heating and Ventilating, Sept., 1950, pp. 88-90.

collector and thereby permit construction economy and ultimate lower heat loss. Researchers at M.I.T. have suggested placing the collector on the south wall and puncturing it with windows for the living areas (*Figure 6*). By abandoning a dominant southern exposure for the living areas, other schemes are conceivable (*Figures 7 and 8*).

The basic premise of forsaking a southern exposure is a questionable compromise. By elevating a structure, a favorable orientation may be given to both the collector and the living areas (*Figure 9*). The large heat loss through the backside of the collector, however, is a serious disadvantage of this scheme.

split collector placement

The basic collector positions may be combined to give a split placement of the collector on the roof and on the ground (*Figure 10*). Such an arrangement compliments human scale and gives dominance to the living area; however, it has the disadvantage of the extra cost involved in splitting the collector.

A slope site has the advantage of providing good orientation for the collector and living areas; it also permits a collector to be separated from a continuous façade and offers good insulation for its backside. (*In Figure 11, scheme "A" has the disadvantage of having its collector plate located away from the home which it is to heat; therefore a high heat loss in transmission can be expected.*)

solar collector design

Having determined a feasible solar house design, the designer must compute the collector size. In the following paragraphs, the calculations required for a collector for a solar house located in the vicinity of New York City (*Figure 12*) will be discussed and solved.

critical months

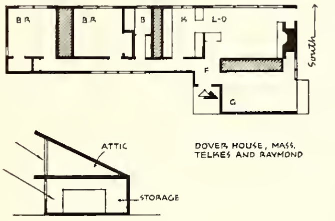
The collector area is governed by the most critical months of the heating season. A factor rating the severity of the heating month may be expressed by:

$$Mc = \frac{\text{Degree days per month}}{\text{Monthly total of average solar radiation}}$$

Because December, January, and February are the most critical heating months for the New York City vicinity (*Table 1*), they will determine the collector size.

collector tilt

The collector tilt and shape is governed by architectural feasibility. Because the maximum solar radiation is delivered from 11:00 am–2:00 pm, the optimum tilt should be based on the corresponding hourly solar angles. The average solar angle, therefore, is 29° resulting in an optimum tilt of 61° (*Table 2*).



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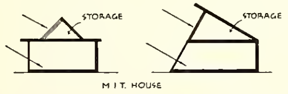

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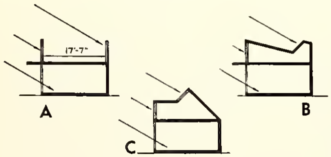

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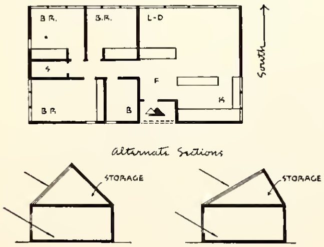

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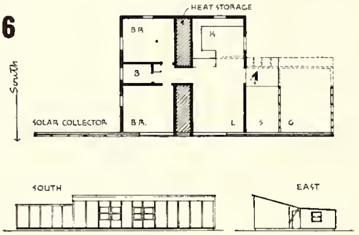

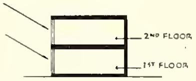

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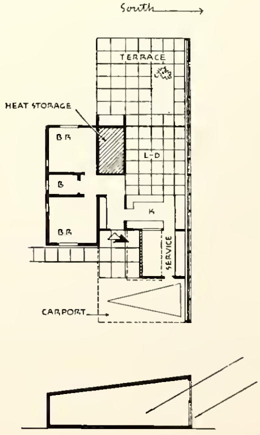

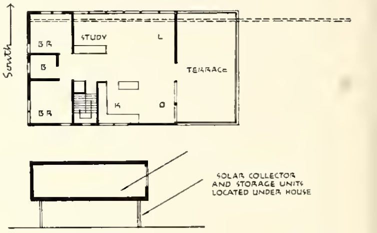

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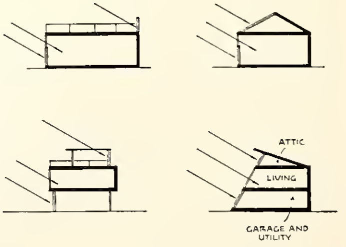

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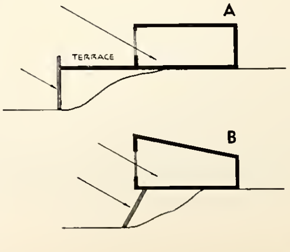

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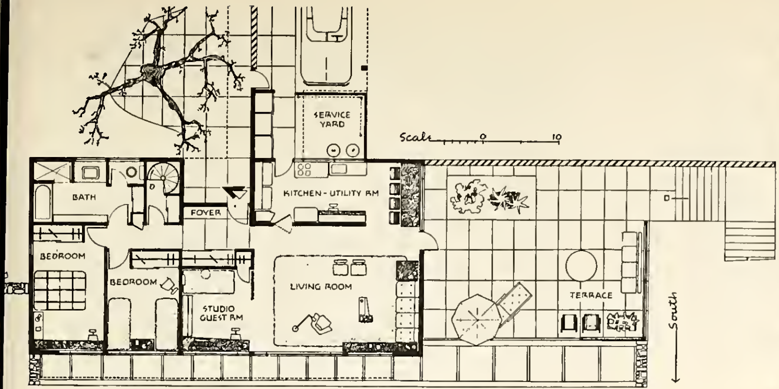


Figure 12

incident solar energy

The energy delivered to a collector may be expressed by (*Equation 1*):

$$q_A/A = (H_s - H_d)\ (\cos \Theta T / \cos \Theta Z)\ \tau\alpha + H_d\ (\cos \Theta T' / \cos \Theta Z')\ \tau'\alpha'$$

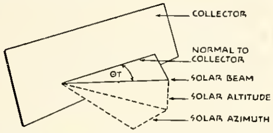
where:

q_A/A = Rate of heat delivered to 1 sq. ft. of collector plate: Btu/hr/ft².

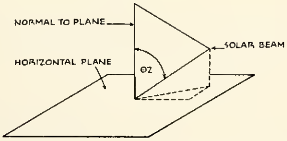
H_s = Total direct solar radiation on a horizontal surface: Btu/hr/ft².

H_d = Diffuse radiation on a horizontal surface: Btu/hr/ft².

$\Theta T (\Theta T')$ = Angle between direct (diffuse) solar beam and normal to the tilted collector surface: Degrees.



$\Theta Z (\Theta Z')$ = Angle between direct (diffuse) solar beam and normal to a horizontal surface: Degrees.



$\tau (\tau')$ = Over-all transmittance, for direct (diffuse) sunlight, of a system of glass plates, allowing for absorption and reflection.

$\alpha (\alpha')$ = Absorptivity of surface of collector for direct (diffuse) solar radiation.

solar radiation: Hs and Hd

Values of direct and indirect solar radiation are obtainable from regional weather stations (*Table 3*).

solar angles: Cos ΘT/Cos ΘZ and Cos ΘT′/Cos ΘZ′

The maximum solar energy strikes a collector when $\cos \Theta T / \cos \Theta Z$ approaches infinity. Having established the collector orientation, the values of $\cos \Theta T$ and ΘZ can be found by descriptive geometry (*Table 4*). The values of $\cos \Theta T' / \cos \Theta Z'$ may be assumed to be 1.

solar transmission: τ

The factors influencing solar transmission through a series of glass plates are the number and type of plates, thickness, and angle of incidence. Two water-white plates (each .117″ thick double-strength glass and separated by an air space) at a 33° angle of incidence will transmit 82% of the incident energy (*Figure 13*).

solar absorptivity

The factors influencing solar absorptivity are the angle of incidence and color of the collector plate. At a 33° angle of incidence, a medium green collector absorbs 96% of the energy absorbed by lampblack resulting in the absorption of 91.2% of the incident energy (*Figure 14*).

incident energy

Because solar altitudes and intensities vary through the day, the incident energy should be evaluated for the morning and afternoon hours (*Table 5*). For all hours, τ and α may be assumed to be constant, $\cos \Theta T' / \cos \Theta Z' = 1$, and $\tau'\alpha' = .61$ (*Table 6*). Evaluating (*Equation 1*), it is seen that q_A/A (morning) = 72.9 Btu/hr/ft² and q_A/A (afternoon) = 70.2 Btu/hr/ft².

usable solar energy

q_A/A represents the solar energy impingent upon a collector. In order to determine the quantity of energy actually utilized for storage, plate dirtiness, transmission losses, and "warming up" of the collector must be considered. The total collectable energy may be expressed by (*Equation 2*):

$$Q_U/A = F[q_A/A(1-D) - q_L/A - q_B/A] - Q_H/A$$

where:

F = Ratio of useful heat collection for the method of heat transmission.

q_A/A = Rate of heat delivered to 1 sq. ft. of collector plate: Btu/hr/ft².

D = Fractional reduction in transmittance of glass plate system due to surface dirt.

q_L/A = Rate of total heat loss through 1 sq. ft. of the top of the collector: Btu/hr/ft².

q_B/A = Rate of total heat loss through 1 sq. ft. of the bottom of the collector: Btu/hr/ft².

Q_H/A = Loss, per collection period, due to heat capacity of the collector: Btu/hr/ft².

lateral resistance: F

The value Q_U/A involves the assumption that the collector plate is at a uniform temperature "T," whereas, a collector design having tubes soldered to the backside of the collector has only an average value of "T" along the contact lines of the plate and pipes through which the fluid flows; it is higher between the pipes. It may be shown that the ratio "F" of useful-heat collection from the latter system to one having a uniform plate temperature is given by

Figures 13-15 and Equations 1-8: H. C. Hottell and B. B. Woertz, "The Performance of Flatplate Solar-heat Collectors", Am. Soc. Mech. Eng. Trans. Vol. 64, 1942, pp. 91-104.

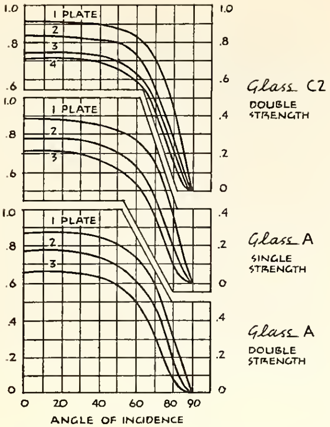


Figure 13—transmittance of glass-plate systems allowing for reflection and absorption losses (above). *Top, middle, and bottom families are for glass with kL per plate equaling .0125, .0370, and .0524 respectively.*

Month	Degree days	Avg. daily radiation on a horiz. surface	MC
September	50	1240	.040
October	272	982	.277
November	594	590	1.05
December	940	450	2.09
January	1028	476	2.16
February	953	731	1.32
March	771	1092	.710
April	465	1410	.330
May	172	1675	.102

Table 1: Severity of heating months for N. Y. C.

Month	Hours	Avg. solar altitude
January	11 am–2 pm	27°
February	11 am–2 pm	36°
December	11 am–2 pm	23°
	Average	29°

Table 2: Avg. solar altitudes of most critical angles for N. Y. C. (above).

Table 3: Avg. direct and diffuse radiation, btu/hr/ft², for Jan. in N. Y. C. (below).

	Hour ending	Total solar radiation	Diffuse radiation: HD	Direct radiation: HS-HD	Total HD	Total HS-HD	Total
Morning 4.65 hrs.	8 am	3.96	.821	3.14	31.9	211	243
	9	27.3	4.78	22.5			
	10	44.6	6.05	38.5			
	11	78.0	9.40	68.6			
	12	90.1	10.8	79.3			
Afternoon 4.97 hrs.	1 pm	88.3	10.1	78.2	34.6	198	233
	2	68.9	9.30	59.6			
	3	44.6	7.85	36.7			
	4	27.3	5.70	19.5			
	Sunset	5.52	1.63	3.89			
	Total	476	66.5	409	66.5	409	476

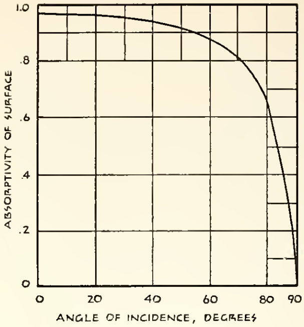


Figure 14—absorptivity of a blackened surface for artificial sunlight transmitted through glass (left).

Figure 15—over-all heat transfer coefficient for use in calculation of heat losses from flat-plate collectors (below). *Tilt from horizontal, 30°; collector surface emissivity, 95; wind coefficient, 4.07, 10 mph.*

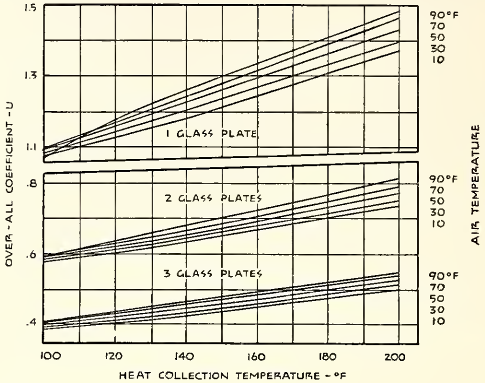


Table 4: Hourly values of Cos θT and Cos θZ for Jan. in N. Y. C.

Solar time	Solar altitude	Solar azimuth	θT	COS θT	θZ	COS θZ	COS θT/COS θZ
8 am 4 pm	9°	124°	57° 30′	.537	81°	.156	3.44
9 3	16°	136°	46° 30′	.688	74°	.276	2.49
10 2	24°	149°	31° 45′	.850	66°	.407	2.09
11 1	28°	163°	15° 0′	.966	62°	.469	2.06
Noon	29°	180°	0′	1.000	61°	.485	2.06
Average	24°	147°	33° 30′	.787	70°	.300	2.47

	Time	HS-HD	COS θT/COS θZ	(HS-HD) COS θT/COS θZ	HS-HD	Avg. HS-HD
Morning 4.65 hours	8	3.14	3.44	10.8	453	97.3
	9	22.5	2.49	56.0		
	10	38.5	2.09	80.5		
	11	68.6	2.06	141		
	12	79.3	2.06	164		
Afternoon 4.97 hours	1	78.2	2.06	161	457	93.9
	2	59.6	2.09	124		
	3	36.7	2.49	91.0		
	4	19.5	3.44	67.0		
	5	3.89	3.44	13.7		

Table 5: Avg. direct radiation. Btu/hr/ft², delivered to 61° collector tilt during Jan. in N.Y.C. (above).

Table 6: Avg. HD, Btu/hr/ft , delivered to 61° collector tilt during avg. Jan. day in N.Y.C. (below).

Period	Avg. HD	HD (COS $\theta T'$/COS $\theta Z'$) $\tau'\alpha'$
Morning	6.86	4.18
Afternoon	6.96	4.25

Period	Outward heat loss QL/A: Btu/hr			Avg. inward heat loss QL/B: Btu/hr	Total collector heat loss QL/A-QL/B: Btu/hr
	U	ΔT	QL/A		
Morning	.57	69°	39.3	1.02	40.3
Afternoon	.57	65°	37.1	1.02	38.1

Table 7: Outward and inward collector heat losses.

Year	December			January			February		
	Dark	Partly cloudy	Above average	Dark	Partly cloudy	Above average	Dark	Partly cloudy	Above average
1941	1	1	4	4	1	5	2	1	10
40	3	2	6	3	1	14	1	1	6
39	2	2	4	2	1	4	2	1	3
38	3	1	4	3	2	4	2	1	3
37	2	2	7	8	1	5	2	1	4
36	2	1	9	3	2	12	2	2	3
35	3	3	8	4	2	7	2	2	3
34	2	3	4	1	2	8	1	2	6
33	4	1	2	1	3	4	1	1	5
32	4	1	9	3	2	3	3	1	6
31	3	1	7	2	2	6	4	1	8
30	3	2	4	7	2	4	1	3	5
29	4	1	4	1	1	6	1	2	5
28	2	3	3	2	2	8	2	2	11
27	3	1	6	4	2	6	4	5	3
26	2	2	2	3	3	3	4	1	2
25	5	1	5	2	2	5	2	5	5
Avg.	2.82	1.65	5.17	3.24	1.82	6.35	2.12	1.88	5.17

Table 8: Max. consecutive number of days.

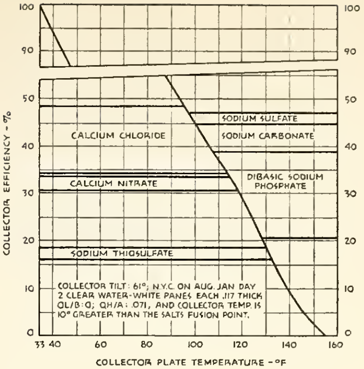
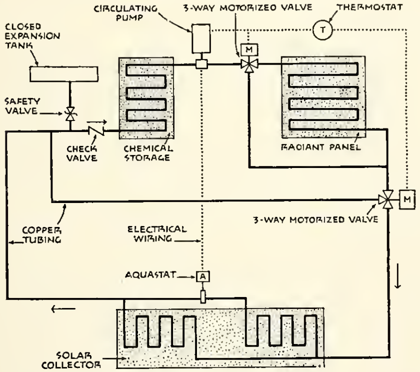
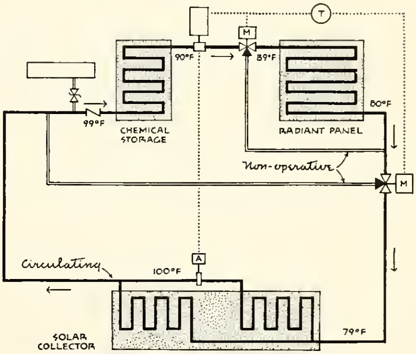


Figure 16—chemical performance in terms of collector efficiency.

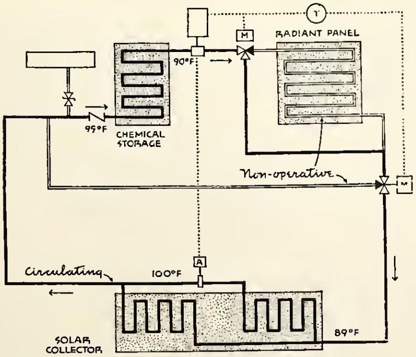
Figure 17—elements of a solar-heating system and the three phases of operation (below).



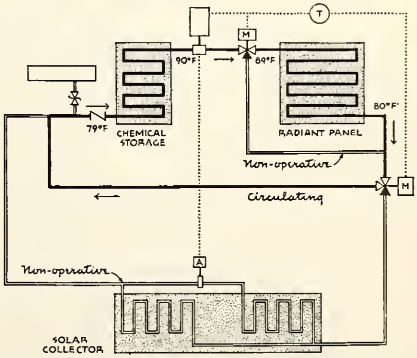
Solar Heating System



Phase I SOLAR ENERGY STORAGE AND HOUSE HEATING



Phase II SOLAR ENERY STORAGE, NO HOUSE HEATING



Phase III HOUSE HEATING WITH STORED ENERGY, NO SOLAR COLLECTION

(*Equation 3*):

$$F=\frac{2}{a}\left(\frac{e^{a}-1}{e^{a}+1}\right)$$

where:

$a = W\sqrt{U'/kM}$

$U' = U+U_D$

U = Over-all loss coefficient, plate to upper air (*Figure 16*).

U_D = Over-all loss coefficient, plate to box bottom, through insulation.

k = Thermal conductivity of collector plate: Btu/°F/ft/hr.

W = Minimum distance between parallel pipes measured along collector plate: Ft.

M = Thickness of collector plate: Ft.

A 24-gage copper collector with ⅜" copper tubes 6" o.c. has an "F" of .975.

plate cleanliness: $1-D$

Dirt and dust deposited by wind, rain, and snow to some extent prevent the collection of solar energy. Tests, however, indicate that window dirtiness is not too detrimental to a collector system. Only .62% of the collectable energy is lost due to collector dirtiness; therefore $(1\text{–}D) = .944$.

outward heat loss: q_L/A

To calculate the heat loss of a collector through its glass panes requires a cumbersome formula. Results of a heat-loss test made with a collector tilted 30° to the equator may be used without serious error for other collector tilts for determining "U" (*Figure 15*). Knowing the over-all "U" for a collector, the outward heat loss may be found in the conventional manner by (*Equation 4*):

$$q_L/A = U(T-T_a)$$

where:

q_L/A = Rate of total heat loss through 1 sq. ft. of the top of the collector: Btu/hr/ft².

U = Over-all coefficient of heat transfer for calculating upward losses from the collector: Btu/ft²×hr °F temperature difference of collector and outer air (*Figure 15*).

$T(T_a)$ = Temperature of collector plate (outer air): °F.

inward heat loss: q_R/A

The inward heat loss is found in the conventional manner by (*Equation 5*):

$$q_B/A = U_D(T-T_a)$$

The heat loss of the collector is shown (*Table 7*).

heat capacity: QH/A

During the morning hours a portion of the absorbed heat is utilized in bringing the glass plates and the insulation below the collector plate up to equilibrium temperature. The heat loss due to the heat capacitance of the collector system may be expressed by (*Equation 6*):

$$QH/A = C(T-T_a)$$

where:

QH/A = Heat loss per sq. ft. per collection period, due to heat capacity of collector: Btu/ft².

$T(T_a)$ = Temperature of collector plate (outer air): °F.

C = Loss due to heat capacity: Btu/ft² collector per °F, temperature difference of collector plate and air per cycle of operation.

The equation for C (*above*) is (*Equation 7*):

$$C=\frac{2}{3}\,q_A/A(T-T_a)\left[\overset{\text{afternoon values}}{\left(\frac{Q_U/A+q_L/A+q_B/A}{q_A/A}\right)}-\overset{\text{morning values}}{\left(\frac{Q_U/A+q_L/A+q_B/A}{q_A/A}\right)}\right]$$

where:

q_A/A = Average value of q_A/A for morning and afternoon: rate of heat delivered to 1 sq. ft. of collector plate: Btu/hr/ft².

$T-T_a$ = Average difference between the temperature of the heat collector and that of the early morning outside air: °F.

Q_U/A = Useful heat collected over a period for 1 sq. ft. involving several cycles of heating and cooling, with allowance for dirt on glass, heat capacity, and fin effects.

q_L/A = Rate of total heat loss through 1 sq. ft. of the top of the collector: Btu/hr/ft².

q_B/A = Rate of total heat loss through 1 sq. ft. of the bottom of the collector: Btu/hr/ft².

Tests indicate that the glass plates and bottom insulation contribute 52% and 28% respectively of the total heat capacity, and the copper absorbing surface and tubes account for but 20%. Solving *Equation 6*, is found that $QH/A = .335$ Btu/hr/ft²/°F.

useful energy: Q_U/A

During an average day in January, in the vicinity of New York City, a collector tilted 61° (having two water-white plates each .117" thick, a 24-gage copper plate painted medium green with ⅜" copper tubes soldered to the backside 6" o.c., insulated with 1" air space, aluminum foil, 4" rockwool, and 1" fiber board) collects 30.9 Btu/hr/ft² and 287 Btu/day. The resulting collector efficiency is 32.3%.

collector size

The collector area may be expressed by (*Equation 8*):

$$A_c = H_L/S_a$$

where:

A_c = Collector area required: Sq. ft.

H_L = Net average heat load: Btu/day.

S_a = Solar energy gathered on a unit area during the most critical heating month: Btu/hr/ft².

heat balance

The heat loss of a solar house cannot be computed as a conventional heat loss problem. Because the solar energy gained for house heating is based on an average monthly value of solar radiation, it is necessary to base the temperature difference on the average outside temperature and not on the regional winter design temperature. The heat balance equation may, therefore, be expressed by (*Equation 9*):

$$H_T = S_M$$

where:

H_T = Total average daily heat load during the most critical month.

S_M = Average daily solar heat collected during the most critical month.

Based on an average outside temperature of 33°F, the heat loss of the solar house is 373,000 Btu/hr. Although the glass area on the south façade loses considerable heat during the evening and inclement weather, it admits a large quantity of heat during an average day which results as an aid to house heating. The total energy gained through 170 sq. ft. of south-facing window is 128,000 Btu/day, resulting in a net heat loss of 245,000 Btu/day. The collector area, therefore, is 850 sq. ft.

chemical storage

In the design of the collector, the plate temperature was assumed to be 100°F. Glauber's salt was chosen because of its efficiency (*Figure 16*). The amount of chemical storage is dependent upon the heat capacity of the salt, heat loss of the house, and the maximum number of days that the house is to be heated solely by chemical storage. For eight consecutive sunless days (*Table 8*) and a 65% efficiency due to heat loss and chemical sluggishness in changing state, chemical storage should be provided for 11 days. During this 11-day period, no heat assistance is considered gained through the south façade. The total heat loss is 4,100,000 Btu; therefore 21 tons of Glauber's salt occupying 434 cu. ft. are required.

solar-heating system

Basically there are three phases of operation for a solar-heating system. *Phase I* consists of solar-energy storage and house heating; *Phase II* consists of solar-energy storage, but no house heating; and *Phase III* consists of house heating with stored energy, but no solar collection (*Figure 17*).

Comfort Factors Affecting Cooling

BY ROBERT H. EMERICK*

Summer comfort may be described by this basic equation—*Metabolism + heat removal = summer comfort*—where:

Metabolism =the production of heat by the human body, varying from 400 Btu per hour at rest, to more than 1400 Btu during physical activity.

Heat Removal=what the designer does to dissipate these Btu.

While the factors of odor, noise, color, bacteria, and air filtration still must be considered for the ultimate achievement of complete comfort (*"Comfort Factors Affecting Heating Design," begins page 233*), the problem of bodily heat removal is of first importance. A slight rise in body temperature as the result of faulty heat removal, is soon followed by a faster pulse, emotional irritation, skin rashes, mental sluggishness and, ultimately—if the body temperature is increased and stays seven degrees or more above normal—by death.

body mechanisms for heat rejection

Our problems as designers for comfort become sharply objective when we examine the body's equipment for heat rejection. In an ambient atmosphere of 72F, we find that nearly half of the total heat production is dissipated by evaporation, illustrated by the 180 Btu of latent heat commonly assumed by designers in their cooling calculations. The remainder, termed "sensible heat," leaves the body by radiation and convection.

This ratio of latent and sensible heat obviously will vary as the ambient conditions vary. If the surrounding temperature comes into equilibrium with the temperature of the skin, then no heat dissipation by either radiation or convection can occur, and the burden of these two mechanisms is transferred in full to the body's evaporative system.

In this state we begin to perspire, starting usually on the face and neck, followed by a gradual spreading to all areas of the body as these additional surfaces are activated to relieve the continuing production of heat. The volume of perspiration emitted by the average person sitting quietly, amounts to approximately 50 cubic centimeters per hour, and the evaporation of this moisture relieves the body of about 110 Btu.

Unfortunately, we must expect the wet-bulb temperature at times to equal or exceed, at least on some areas of the body, the temperature of the skin, and during these periods no evaporation can take place. These 110 Btu then, if not dissipated soon, commence to lift the temperatures of our tissues and the possible result is illustrated by the dramatic Calcutta incident of June 20, 1756. On that night 146 persons, generating a minimum of 58,400 Btu per hour, were confined in a room that allowed less than two square feet of floor space per person. In the morning, only 23 remained alive.

humidity versus temperature

So long as the relative humidity remains at 50 percent or less, evaporation takes place at an adequate rate from the human skin. Control of the humidity for comfort, therefore, becomes essential as the ambient air temperature enters the high 80's and the 90's.

In many sections of the Southwest, evaporative cooling is practical with rather wide satisfaction, additional mechanical refrigeration often being judged unnecessary for comfort. However, we seldom can expect to cool closer than six degrees to the wet-bulb temperature, and in areas where a 78F wet bulb is common, evaporative cooling will not suffice.

Humidity control in these humid regions therefore, is accomplished by mechanical refrigeration, or by the application of adsorption processes in silica gel machines, or by proprietary fluids that abstract moisture from the air as the air passes through a spray of the fluid. Either of the chemical systems requires temperature cooling as a supplementary aid to comfort.

The combination of chemical dehumidification and mechanical refrigeration versus a mechanical system that does both, is a problem of economics. Particularly where we have a strong demand for fresh air, (as in night clubs), chemical dehumidification followed by mechanical cooling, may show substantial economic savings over a straight mechanical system. This sort of arrangement is employed with notable success in the Hotel Willard, at Toledo, Ohio.

thermal shock

There is nothing we can do at the moment to eliminate the thermal shock experienced on entering a cooled room from a hot street, or conversely, on leaving the room for the street.

To limit the shock, we attempt to design cooling systems for a differential of 12 to 15 degrees, but unfortunately this differential often is inadequate to supply comfort to persons more or less permanently housed in the cooled space. The need for a much wider differential when the outside temperature is, say 95F, is a direct result of humidity. An ambient of 83F is literally too close to our skin surface temperatures for comfort, since radiation and convection largely decrease or stop, and the dissipation of our 400 or more Btu per hour becomes the complete responsibility of evaporation. In the circumstances, the rate of evaporation tends to be too slow; a feeling of discomfort soon develops, and being human we promptly reset the temperature controls to give us, not 83F, but 72F. We thus re-establish radiant and convective cooling for our skins, but the newcomer to our room is met by an unintentionally chill atmosphere.

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* *Consulting Mechanical Engineer, South Charleston, South Carolina.*

Undoubtedly we need practical research into the achievement of comfort at relatively high temperatures, when experienced in combination with controlled low humidities. We possibly may alleviate thermal shock by following this avenue, but meanwhile we need not worry about injurious effects, because there are none. During the recent war, this writer was responsible for the design and installation of air-conditioning systems in the sick bays and operating rooms of many warships in the South Pacific; and in numerous post-battle inspections, the doctors were questioned about thermal shock and its possible dangers. Invariably it was reported as being of no consequence.

drafts

The effect of air movement is mainly this: as the moisture on the surface of the skin evaporates, it saturates the air in contact with the skin and then evaporation stops. If we now remove this stratum of saturated air and replace it with relatively dry air, the evaporative process is re-established and cooling follows. This exchange of saturated air for dry air is readily accomplished by the winds of nature or the breeze of a fan.

Winds and breezes however, if not controlled, may become unpleasant drafts, and in this state will frequently cause pain in an occupant's neck. *(Table I has been developed by various researchers as a guide to what is desirable in air movement; designers will do well to observe it.)*

Direction also can be important in avoiding discomfort from drafts. For example, Figure 1 illustrates a common arrangement for summer cooling found in small retail stores. In this banking room, the certainty of chilled drafts striking the backs of clerks and tellers is obvious. In short, comfort has been purchased but only stiff necks have been delivered.

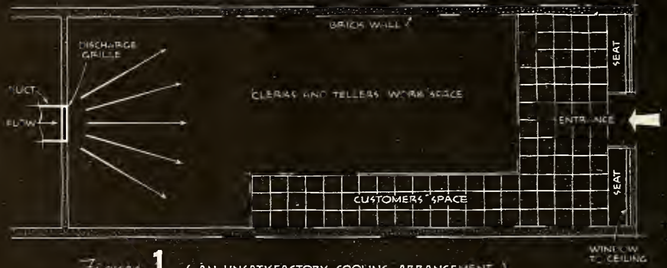


Figure 1 (AN UNSATISFACTORY COOLING ARRANGEMENT)

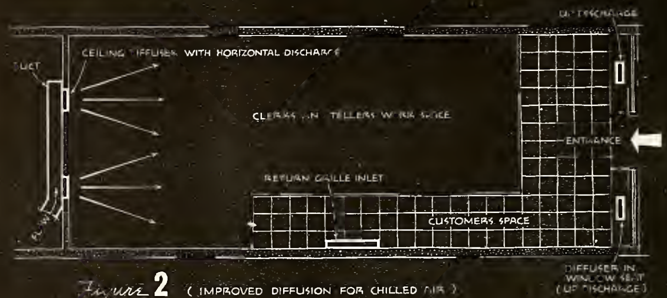

UP DISCHARGE
CEILING DIFFUSER WITH HORIZONTAL DISCHARGE
DUCT
CLERKS AND TELLERS WORK SPACE
ENTRANCE
RETURN GRILLE INLET
CUSTOMERS SPACE
FLOW
DIFFUSER IN WINDOW SEAT (UP DISCHARGE)

Figure 2 (IMPROVED DIFFUSION FOR CHILLED AIR)

Figure 2 offers a better solution for cooling a room of this kind. Discharge velocities are reduced by half and in the front of the room, where the major load occurs, the large windows are blanketed by curtains of cool air emerging from ceiling-type diffusers set to blow upward from the window seats.

Air movement provides what is probably the cheapest of all means to summer comfort. Even the attic fan, or the window fan, both common in the small home, so aid the evaporation of moisture from the skin that considerable comfort is enjoyed by people not otherwise able to secure it.

comfort and solar impact

Here is a problem, aside from the delivery of heat from the sun to the human body, that must be solved by the architect. A Cleveland man once told this writer, after a winter visit to Florida, that the impact of brilliant sunlight gave him a feeling of such discomfort that he abandoned his trip and hurried back to the gray skies of Cleveland. Conversely, it is not difficult to find people who exhibit a facsimile of the sun-worshipper attitude.

Unfortunately, many do not recognize these peculiarities in themselves prior to actual experience. The Cleveland man dreamed of Florida until he visited there; the successful salesman builds his dream home in the heart of a suburban woodland and then discovers that surrounding himself with trees instead of people gains him nothing but loneliness and discontent.

The significance of these emotional reactions is important to any evaluation of comfort, since nothing the mechanical designer can do will suffice to bring comfort where the architect has provided the wrong orientation for his client. For a good job all around, the architect must sense the psychology of the people who retain him, providing solitude for the introvert, giving the extrovert a bright place in the sun.

Often the house site is chosen before the architect is called in. In these instances, much can be done by the planting or removal of trees, and by skillful application of color.

the importance of floors

Chiropodists tell us that many pains and aches originate in some maladjustment of the feet. This writer has had clients who reported a swelling of the feet and ankles, with considerable pain, the cause of the trouble being ascribed to the cement floors in the home. That some truth exists in the claim is illustrated by the fact that, after wood floors were laid on the concrete, both the swellings and the pains disappeared. Some measure of resiliency in the floors seems desirable, but again, everybody is not adversely affected

Table I: Effects of Air Velocity

Velocity, feet per minute	Probable impact on persons
Up to 50	Unnoticed.
50 to 100	Pleasant.
100 to 200	Generally pleasant but causing a constant awareness of air movement.
200 to 300	From slightly drafty to being annoyingly draftly.
Above 300	Requires corrective measures if work and health are to be kept at high efficiency.

Note: These velocities are higher than recommended by the A.S.H.V.E. Guide, 1951 Edition. However, when walking through still air at 2 miles per hour, the speed of the walker, relative to the air, is 176 feet per minute and the sense of air movement at this rate is moderate and not unpleasant.

by a nonresilient floor. The phenomenon is a personal one but certainly should be considered when designing for comfort.

A cold floor in the summertime, likewise, can give rise to physical ailings. During the recent war, a ship in the south Pacific reported many complaints from a certain compartment in which colds, aching feet, even some suspected arthritis, indicated that an investigation should be made. This compartment was located directly above a refrigerator room and the steel deck was consistently cool, sometimes damp. The compartment deck was then floored with two inches of fiberglass insulation, sealed with a hot mopping of bitumastic, and finished off with a layer of cement. The complaints ceased. Incidentally, the steel decks of ships rarely cause foot trouble, since they normally are of thin plates and provide some degree of resiliency.

The problem of cool floors is not a common one, but it must be considered if cold water is run through the tubing of a radiant floor panel for summer cooling.

summarizing summer comfort

A summary of "dos" and "don'ts" for designers of summer comfort, is shown on Chart 1. Each is important, but in most cases a control of the humidity will be found the shortest road to a comfortable end.

Chart 1: Summer Comfort Design Considerations

Provide	Method
Humidity control	a—Mechanical refrigeration with sub-dew point cooling plus air mixing or reheating.
	b—Adsorption equipment, as silica gel or liquids.
	c—Air precooling with cold water coils or ice.
	d—A combination of a and b, or a and c.
Temperature control	a—Mechanical refrigeration.
	b—Cold water cooling.
	c—Either of the above plus air circulation and mixing.
	d—Evaporative cooling where the wet bulb permits.
	e—Insulation of building roof and walls.
	f—Adequate shading against the sun.
	g—Color selection to reject or absorb sunlight as desired.
	h—Proper use of natural orientation, to take advantage of exposure, trees, prevailing winds, etc.
Air movement and ventilation	a—Gentle air movement by fans.
	b—Correct location of air inlets, particularly chilled air.
	c—Screen or filter air intakes to eliminate dust, insects, and pollen as well as practicable.
Resilient floors	a—Finish concrete or cement with asphalt tile. Alternatively lay wood, either with or without sleepers. Reports are satisfactory on both methods.
Solar impact compensation	a—Consider sun effect when designing the structure, particularly residences where emotional reactions may sometimes follow.

Don't permit	Method
Drafts	a—Maintain air velocities at less than 100 feet per minute, if the moving air impacts on persons.
	b—If the air is chilled before delivery, introduce it well above the head level.
Clamminess in conditioned spaces	a—Maintain the relative humidity at less than 50%.
Inadequate air change	a—See that at least 30 cfm of air is delivered to each person.
	b—In the total air delivered, provide at least 15 cfm per person, from outdoors.
An inexperienced person to design the system	a—Verify the record of engineers and contractors before making a commitment.
Odors, pollen, dust, etc.	a—Follow the methods described under the heating cycle, for comfort.

How to Choose a Comfort Cooling System

BY ROBERT H. EMERICK*

To make a reasonable choice in any field one must understand the alternates available. For comfort cooling these alternates include: mechanical compression systems, absorption cycles, steam jet arrangements, designs with ice, and plain cold water from the nearest well. Let's see what we can expect from each.

the case for mechanical compression

These systems, currently dominating the market, employ the basic arrangement of compressor, condenser, evaporator, expansion valve, and air moving fan. These are illustrated by Figure 1.

For small loads, say up to 15 tons, most of the mechanical compression circuits are concealed within the smartly finished cabinets of the familiar package coolers. These units are push-button controlled, uncomplicated in appearance, and notably flexible in their application. We can use them to supply cool air to a duct distributing system or simply allow them to discharge into the room wherein they stand. Service too, is quite simple—hardly more difficult than for a domestic refrigerator—a skilled service man can replace an entire compressor in two hours or less.

Wherever we have a load within the range of a package unit, and most retail specialty stores and professional offices are within such a range, this solution is likely to be the simplest and best. Some installations will use city water for condensing the refrigerant; however, at a rate of 1½ gallons per minute for *every* ton of capacity, the expense may become an item to be reckoned with. If we can't stand the cost of water then we must install a cooling tower which enables us to use the same condensing water over and over again. Air for condensing is not practical for units larger than 1½ tons, under average summer conditions.

Table 1 indicates the floor space and headroom we should provide for these package coolers, although some variation from these dimensions must be expected.

The installed costs will range from $300 to $600 per rated ton of capacity, depending on the need for ducts, cooling tower, structural changes and reinforcements for the building, and finally, the status of local competition. Operating costs of course, depend on the hours of use and existing electric rates; within the range of 5 to 15 tons capacity an estimate of $6.00 per ton, per peak month, might be a reasonable average.

package units for large loads

By grouping a number of small cabinets we have a means, although not always the best one, of meeting a large load. The advantage of this plan is an obvious one: all units are not likely to break down simultaneously. On the other hand two serious disadvantages are incurred: first,

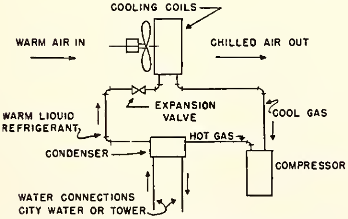


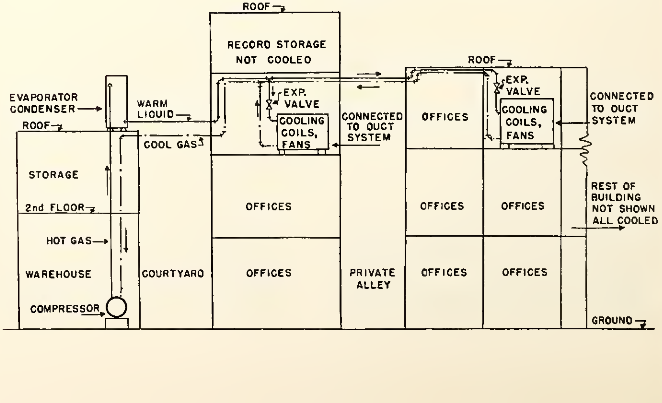
Figure 1, above: mechanical compression circuit.

Table 1: Small Package Coolers

Rating tons or hp	Width inches	Depth inches	Height inches	Air cfm
1*	38	20	40½	360
3	46	24	73	1200
5	49	20½	95½	2000
7½	73	38	73	3000
10	73	38	73	4000
15	102½	28	104	6000

* Air-cooled condenser, all others water cooled.

Figure 2, below: dispersed central plant arrangement.



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* *Consulting Mechanical Engineer, North Charleston, South Carolina.*

Table 2: Large Package Coolers With Built-In Evaporative Condensers

Ratings tons or hp	Width inches	Depth inches	Height inches	Air handled by conditioning fan, cfm	Air handled by condenser fan, cfm
15	110	42	74	7000	4400
20	110	42	74	8000	5000
25	122	48	77	10,000	6000
30	130	54	85	12,000	7500
40	140	60	90	16,000	10,000

Table 3: Component Parts Data

	Rating		Length inches	Width inches	Height inches	Weight pounds
Compressors	15	Tons or hp	82	36	49	2100
	20		82	37	49	2180
	25		82	37	49	2200
	30		82	37	49	2240
	40		82	37	50	2650
	60		106	44	52	4240
	75		106	44	54	4700
Air Mover and Filter Units	3-8	Tons	95	44	29	Variable, from about 300 to 2,000 pounds, depending on number of coils, inclusion of dampers, etc.
	8-16		102	71	29	
	16-24		102	71	39	
	16-33		102	71	49	
Cooling Towers	2½	Tons—80F wet bulb	66	30	40	500
	4		102	30	40	650
	6		102	30	52	800
	8		102	30	64	950
	10		102	30	78	1100
Evaporative Condensers	10	Tons	74	30	55	1550
	15		61	30	88	1900
	20		61	30	94	2100
	25		70	30	97	2500
	50		98	30	116	4300
	75		100	30	129	5500
	100		110	30	142	7200

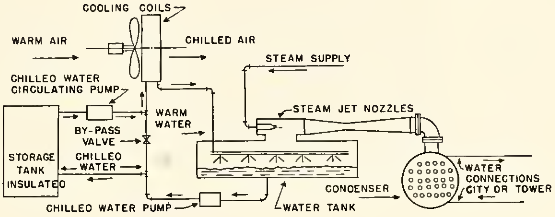


Figure 3, left: steam jet circuit.

if we can obtain equal capacity in a single unit, we are paying a premium in space for the multiple arrangement; second, the duct, damper, and control arrangements are likely to become quite complicated. Economically a multiple installation is unfavorable under most conditions.

Instead of the multiple plan we can substitute a large package unit. This type is available, from a reduced number of builders, in a single cabinet and in capacities up to 40 tons. An important feature of this package is the inclusion of an evaporative condenser in the common housing, thus providing a system all in one unit. However, the evaporative condenser requires fresh air in large volumes; we must bear its warmed bulk to the wide open spaces in even greater volumes, a feat that sometimes involves considerable duct work.

The physical dimensions of these big plants can make their location quite a problem, as emphasized by Table 2. In short, they find themselves competing with the "tailor-made," or dispersed type of central plant in which we locate the compressor in one place, the air mover unit or units in another, the cooling tower or evaporative condenser in still another.

the "tailor-made" or dispersed central plant

Figure 2 illustrates the procedure of lifting components of a system from the cabinet, for assignment to suitable areas often widely separated.

The practice enables us to set our machinery in the least essential areas and offers a way to reduce or eliminate long duct runs. This arrangement is common for very large systems since it is applicable to one building, or to several. If our load is much above 15 tons we certainly should study this possibility; the building features and the nature of its occupancy will provide a guide.

In these preliminary studies the data in Table 3, which indicate dimensions of component parts, should be quite helpful. By cutting paper templates and laying them on a drawing or sketch, we may see at once the wisdom of further investigation or abandonment of the idea.

From the investment standpoint we can expect to pay from $250 to $450 per rated ton for a dispersed central plant arrangement, depending on the situation encountered. These prices will include everything.

Operating costs, once we go beyond 15 tons capacity, begin to be affected by the demand factor that commonly appears in the rate structure for electric service. Consequently, a large comfort cooling installation, although operated but a few months in the summer, may impose on the owner a demand charge that is assessed every month throughout the year. This possibility deserves particular attention for structures of irregular or limited use, such as churches.

the steam jet picture

A dispersed central plant can be formed with somewhat less facility by using steam jets on a water tank, instead of the mechanical, motor-driven compressor. With this arrangement the condenser by necessity must be mounted contiguous to the jets but the cold water, which serves as the refrigerant, can be pumped to coils and air moving fans located anywhere.

The functioning of the steam jet system is illustrated by Figure 3. The steam jets create a vacuum above the surface of the water, and since water boils right down to 32F if the vacuum is great enough, the steam jet system is suitable for all installations above freezing. The heat of boiling, or vaporization, separates from the main body of water at a rate of 1000 Btu or more (depending on the vacuum) for every pound of water evaporated; consequently the water under the steam jets grows colder and colder and we can control the temperature by controlling the vacuum. The cold water is pumped to the air cooling coils wherever they are.

The appearance of a steam jet installation is illustrated by Figure 4. Here we see the jets on the tank, the condenser, and the pump for circulating the cold water. We do not see the cooling tower nor the cold water storage tank that, insulated with cork, frequently is a necessary auxiliary for a steam jet system.

The space requirements for the equipment shown in Figure 4 appear in Table 4. The dimensions of the storage tank can be whatever we wish.

Steam jet installations, complete, will cost from $150 to $300 per rated ton, the unit cost descending as the capacity increases.

Considering both space and initial cost factors, the steam jet system compares favorably with the conventional mechanical compressor installations. It is simple to operate; except for the chilled water pumps, it has no moving parts. However, its economical operation depends entirely on the availability of low cost steam, say $1 per thousand pounds or less. Where district steam service is at hand, steam is often available at this price during the summer months; however, if the system must be used at other periods of the year, a steam demand charge may upset the whole economic balance.

Table 5 shows the steam required per ton of steam jet refrigeration, at various pressures, and the quantity of condensing water needed. Obviously, the higher the pressure, the better the economy of operation. Higher pressures, however, tend to increase the rate of erosion on the steam jet nozzles; for superheated steam, nozzles of stainless steel or monel offer good resistance. Maintenance costs generally are low for there is little to wear out; this is one of the steam jet system's notable advantages.

what about absorption systems?

Figure 5 is a refresher diagram of the absorption circuit.

For comfort cooling, the application of the absorption principle is encountered mostly in small cabinet units of 3 to 5 tons capacity, generally fired with gas, and similar in their combustion features to the gas fired refrigerator.

Compared with mechanical compression package plants of the same size, these absorption designs are likely to have a higher purchase price, but over a period of 20 years or so their low operating costs often produce a lower over-all owning charge. This is particularly true if the local gas rate averages less than 90 cents per 1000 cubic feet, for the

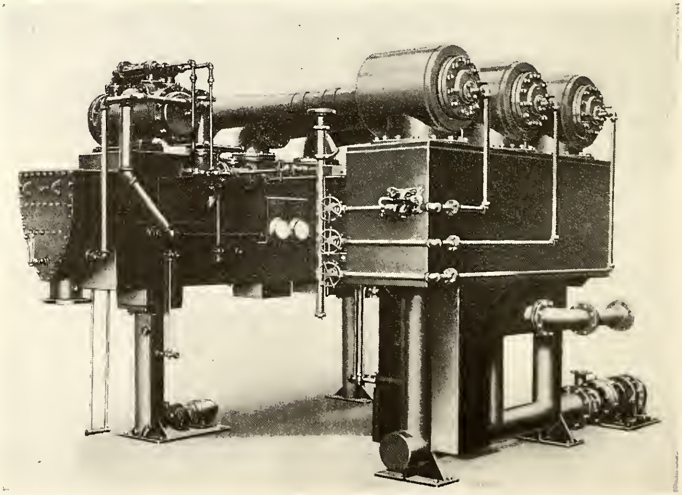
Table 4: Dimensions of Steam Jet Plants

Rating tons	Length inches	Width inches	Height inches
20	72	120	108
40	114	150	120
75	144	150	132
100	150	180	132
200	180	216	156

Table 5: Steam for Steam Jet Systems

Steam pressure psi. gage	Pounds of steam per hour per ton	Condensing water gpm per ton
Under 10	45	9.0
20	38	7.8
30	35	7.3
40	33	7.0
50	32	6.8
60	31	6.7
70 and above	30	6.5

Figure 4, below: steam jet cooling plant.



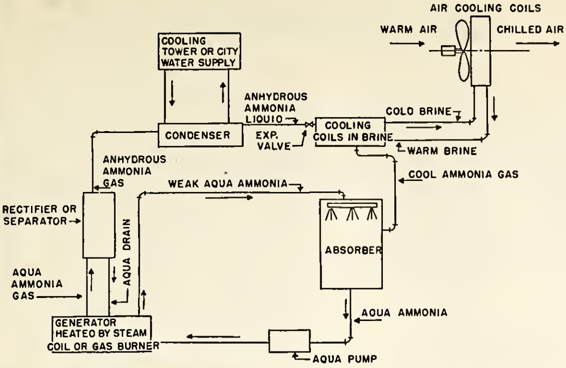


Figure 5, above: ammonia absorption circuit.

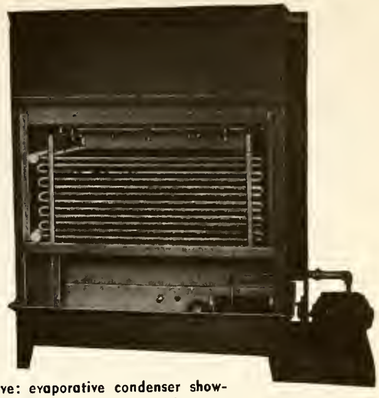


Figure 6, above: evaporative condenser showing refrigerant coils and water sump; fans are in top.

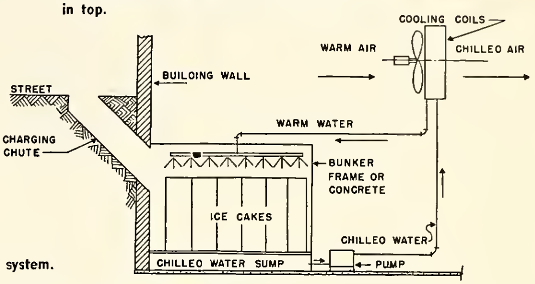


Figure 7, right: ice bunker system.

first 10,000 cubic feet used each month.

Since both cooling and heating facilities are housed in the same cabinet of an absorption conditioner, a direct comparison with other forms of conditioning requires us to evaluate the over-all picture. That is, we should add the costs of a heating plant to the conventional mechanical compression arrangement and thus strike a figure for all year operation.

The advantages of the absorption cabinets are these: a probable lowest lifetime owning cost; a reduction of moving parts by eliminating the compressor; a somewhat lower noise index, due to the absence of the compressor.

The disadvantages are these: in many communities service will be non-existent or haphazard; as with other systems of cooling, they require pumps and a cooling tower; their small unit capacity soon introduces the need for multiple installations.

Below are the physical dimensions of the absorption cabinets:

Capacity in Tons	Width (Front)	Depth (Side)	Height	Weight
3	66¼″	57½″	84½″	2150 lbs.
5	66¼″	57½″	84½″	2485 lbs.

Minimum room dimensions acceptable for maintenance: 7′-0″ x 8′-0″; 7′-4″ ceiling.

The cost of these all-year conditioning units, if charged against cooling capacity only, runs around $1100 per ton; if assessed against the heating cycle, $38 per thousand Btu. These figures show the fallacy of using anything less than a full year's service when attempting an evaluation of a bid.

the towers and evaporative condensers

Since one or the other of these apparatus is needed for the mechanical compression, steam jet, and absorption circuits, some idea of their sizes and weights is desirable.

Most of these units are seen on roofs; actually we can locate them everywhere, on the ground, even indoors, provided we give them enough air. In the tower the condenser water is cooled by simply spraying it into a stream of air where six or eight percent evaporates and cools the remainder. The evaporative condenser works similarly except that the cooled water falls over a coil into which the refrigerant enters as a gas and leaves as a liquid, minus its heat of evaporation. The advantage of the evaporative condenser is a physical one, as it combines the condenser and cooling tower in a single housing. It is not applicable to the package coolers which contain their own built-in condensers, and we must use towers for these.

In either case, the water is recirculated again and again and only that lost by evaporation, a rather negligible quantity in most installations, must be supplied.

Natural draft towers are the cheapest to buy; however in humid climates they are not satisfactory as the relatively small volume of air passing through them is quickly saturated and thus checks their cooling. Forced draft towers with fans and motors are essential, therefore, in such climates. Fans are standard equipment with evaporative condensers.

Table 3 presents physical facts for this group of apparatus; Figure 6 is typical of the evaporator condenser.

comfort from ice

Figure 7 illustrates an arrangement that cools by co-operation of the iceman.

As ice melts very fast when sprayed with warm water, we can obtain a great deal of cooling for a short period. For example, one ton of ice will absorb 288,000 Btu in melting; if our spray water melts it in an hour we have accomplished 24 tons of cooling since 12,000 Btu is the measure of a single ton in a single hour.

Churches, theaters, and similar centers of short occupancy have used the iceman system with considerable satisfaction. Installation expense is not heavy, since we can build the ice bunker of any size we wish. Ice costs vary with location but $8 per ton might be used as an average.

the cold water way

If we have a well handy that delivers cold water abundantly or even a chilly lake or river we can forget other schemes for summer comfort and simply pump the cold water into our cooling coils. When nature furnishes the cold water, this is the cheapest scheme of all.

first cost is not all

In considering a comfort cooling system a crucial question is: which one actually is best economically?

First price can be quite misleading since the economics of an installation include operating expenses, maintenance costs, amortization, even space assessments if space is available.

Here is an analysis for example, of bids received for an all year plant in a large residence of 18 rooms:

Item	Lowest Bid	Next Low Bid	3rd Low
Quoted Price	$9532.95	$9649.50	$10,082.96
Annual Operating Cost*	1609.96	1507.95	1465.16
Total Owning Cost, 20 Yr. Life	41,732.15	39,808.50	39,386.16
Extra Cost of Owning	2345.99	422.34	0

* Includes interest on investment @ 4%, electricity at 5 cents per kwh, estimated maintenance based on judgment and records and amortization.

Obviously the low bid here was not the most economical bid, not by more than $2000.

Another factor of importance in evaluating bids is the item of excess capacity; we might call it a factor of safety. In one large job recently analyzed by the writer, the low bid was remarkable by its exact meeting of the specifications, there was no leeway anywhere. On the other hand, the next low bid, $500 higher, provided more than three tons of excess capacity which could be devoted at a later date, if the owner wished, to an extension of the cooled areas. In 20 years the low bid was still low, but by less than $20 so the owner decided those 3 tons were certainly worth $20 to him and placed the contract with the next to lowest bidder.

The final choice of cooling system should be made only after careful evaluation of two basic factors, the first factor being the physical characteristics of the system, the other the economic. The latter must be calculated from the bids received but for the first the chart of characteristics, Table 6 should offer some initial help.

Table 6: Characteristics of Systems

System	Especially suited	Less suitable	Condenser water cooler	Remarks
Small Package Coolers, Mechanical Compression	(a) Homes, offices, small stores (b) Loads under 15 tons (c) Space or duct arrangement	(a) Large loads (b) Multiple arrangement	Tower or city water	Commonest of comfort coolers. Wide choice of manufacturers. Easy service
Large Package Coolers, Mechanical Compression	(a) Central plant duty (b) Loads from 15 to 40 tons (c) Where owner wants a big plant in a single housing	(a) Space may be unfavorable (b) Condenser ducts may complicate installation	May have built-in evaporation condenser. Otherwise uses tower	Competes with tailor-made installations
The Tailor-Made or Dispersed Central Plants, Mechanical Compression	(a) Loads above 15 tons (b) Minimizing duct runs (c) Supplies scattered load requirements (d) Excellent for large buildings or multiple buildings (e) Easily assembled with components from various manufacturers	(a) Small loads (b) If units are scattered supervision is difficult	Tower or evaporative condenser	Now serving the bulk of all installations over 15 tons
Steam Jet	(a) Medium to large loads, above 20 tons (b) Cheap steam (c) Tailor-made or dispersed central plants	(a) Economic justification needs cheap steam (b) Headroom may be a problem (c) Large water storage tank may be hard to work in	Tower	Many installations along district steam mains, especially for large loads
Absorption Package Cooler Gas Fired	(a) Homes, offices, small stores (b) Loads under 10 tons (c) Low gas rates (d) Provides all-year conditioning from a single cabinet	(a) In areas where skilled service not available (b) Initial costs tend to be relatively high	Tower	Choice of models and makers quite limited
Ice Bunkers	(a) Heavy loads for short periods (b) Buildings with irregular usage	(a) Costly for long and steady loads (b) Ice handling is sometimes messy (c) Must be built to order	No condenser	One of the early arrangements for comfort cooling
Natural Cold Water	(a) Cheapest cooling where available	(a) Cooling range limited by temperature of water	No condenser	Usable in few areas

Two Air-Panel Cooling Systems

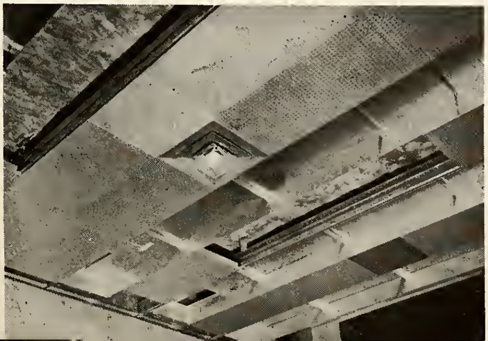
BY BURTON H. HOLMES

Interest in panel cooling continues to grow and as a result of the research performed by many engineers, most of the technical problems associated with this type of environmental control have been solved. To date, the most noteworthy panel-cooling installations have been a pilot project for one floor of the TIME-LIFE Building, New York, a system for the Manufacturers Life Insurance Company of Toronto (both designed by Philadelphia Engineer Charles Leopold), and a system for the new 30-story Aluminum Company of America office building now under construction in Pittsburgh (Jaros, Baum & Bolles, New York, collaborated with Alcoa engineers in this solution). Using the design knowledge available today, these systems can be constructed at costs not exceeding those for conventional air-conditioning installations; in addition, they permit an increase in rentable floor area for commercial buildings as well as a reduction in story heights. For a detailed analysis of this cooling method read "Design Factors in Panel and Air-Cooling Systems" by Charles Leopold, March and April 1951 PROGRESSIVE ARCHITECTURE.

During the last year, John D. Dillon & Associates, New York engineers, have experimented with two air-panel-cooling methods and, recently, interested architects, engineers, and prospective clients have had an opportunity to visit their laboratory at Port Washington, Long Island. Built under an unused carport at the residence of Richard Geomann, a member of the firm who performed the research and development of these two methods, this laboratory consists of a model test room and its related mechanical equipment. Measuring 11′ x 10′ and 6′-1″ in height, the test room actually contains two independent panel-cooling installations—one in the ceiling and the other in the floor. In contrast with the designs of Leopold, Jaros, Baum & Bolles, and the Alcoa engineers (cited above) which utilize water as the cooling medium, both methods demonstrated at the Dillon laboratory are dependent on cooled air. The following basic mechanical equipment was required for the test observations: one two-ton, air-cooled compressor with a direct-expansion-cooling coil; master, sub-master pneumatic temperature control set up to bypass the cooling coils; and numerous thermo-couples in both ceiling and floor to record complete test results.

The ceiling is surfaced with aluminum, radiant-acoustical units (*Figure 1*) manufactured by the Simplex Ceiling Corporation, New York. Cooling ducts (12″ x 4″) are interlocked with acoustical panels (12″ wide and five percent of the area perforated); both units are produced in lengths up to five feet. The tops and sides of the ducts have a low emissivity rate due to the use of mill-finish aluminum; the bottoms, however, have been anodized to increase their rate of heat absorption. Fluorescent troffers integrated with the ducts and panels are attached to the structural ceiling by a direct suspension system. A one-inch layer of glass-fiber insulation is located eight inches above the flush panels.

Figure 1—fluorescent troffers and the bottoms of some air ducts have not yet been placed in this partially assembled panel-cooling system.



Under test conditions, the ceiling panels operating independently with low-velocity air circulation account for 80 percent of the cooling load; the remaining 20 percent is balanced by convective air which enters the room through 12″ x 12″ diffusers integrated with the acoustical panels. This diffuser, an Anemostat product, is particularly suitable for this installation as it emits air in a plane parallel to the panel cooling surface. A 54F ceiling temperature is not uncomfortable on persons in a seated position. A four to six degree temperature differential was found to exist between the panel and structural ceiling; it has been noted, however, that this differential conveniently assists the system to even out the temperature in the acoustical panels.

Cellular steel panels (Type RK) manufactured by the H. H. Robertson Company are used as structural floor units as well as ducts to carry the cooled air *(Figure 2)*.

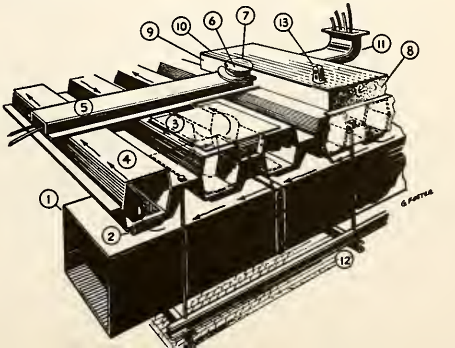
Operating with medium-velocity-air circulation, the floor panel was designed to take care of 60 percent of the cooling load—the remaining 40 percent to be offset by convection. Although these proportions were considered most suitable for this test installation, it is acknowledged that the relationship would change with the differing types of occupancy that the system would be called upon to serve.

During the tests, it was not considered uncomfortable or uneconomical to operate with a 30-degree temperature differential between air supply and room temperature—a conventional air-conditioning system would probably operate with a 15-degree differential for comfort conditions in a room of the same size. During a demonstration attended by the writer, the room temperature was 67F while the outside temperature was 80F and the humidity 70 percent. It was observed that on days when there was a sufficient solar heat gain, it was possible to operate the floor system with a surface temperature of 61F without discomfort to the occupants. During the night, however, when the wall surfaces had cooled down, the 61F floor temperature became unpleasant.

The Dillon Associates have designed the first air-panel-cooling system for an office building; this structure is now under construction at New Canaan, Connecticut. Using a cellular-steel, floor-type, panel-cooling system, the mechanical contract came to only eight and one-half percent of the total construction cost. These engineers have estimated that in comparison with a conventional air-conditioning system, these air-panel-cooling installations can effect a savings of up to 30 percent in operating costs.

Figure 2—legend:

1. Supply air duct
2. Sheet metal duct collar
3. Q-floor turn (180°)
4. Structural floor
5. Crossover wireway
6. Hand hole (into the cell)
7. Adaptor plate (covering used hand hole)
8. Q-floor sealing plate
9. Lightweight fill (usually 2½ inches)
10. Floor finish
11. Ell connecting the crossover wireway with the panel box
12. Suspended ceiling (7/8″ vermiculite plaster)
13. Floor outlet head (can be set anywhere along cell)



Planning for Residential Air Conditioning

BY WILLIAM J. McGUINNESS*

Air conditioning in the home, once considered a luxury, is now taking its place as a requirement for comfort and efficiency. The air conditioning of public and commercial buildings has been an established practice for the past 30 years. During this period, there have been many predictions that within a few years it would be quite universal in residences. These predictions have not in the past been fulfilled. Are there reasons for this default which still impede the program or may we hope for great progress based on the present activity in residential cooling? There seems to be reason to believe that new installations will be better, cheaper, and easier to install and operate.

Let us examine the history of cooling in homes. In spite of the development in 1930 of Freon, a nontoxic and nonexplosive refrigerant suitable for small as well as large systems, the expected acceleration of central cooling in homes did not occur in the 30's. This was due to the depression. In 1940, it was thought that within 10 years a large part of the population would live in conditioned homes. World War II dispelled this hope by confining the use of conditioning equipment to essential operations and delaying the residential program by at least five years. The present availability of standard and suitable equipment and the development of simple and effective design methods now give promise that within five more years residential air conditioning will finally be in the same category as automobiles and refrigerators. Room air conditioners have been a partial solution but have actually impeded the progress of central cooling. Sales now indicate that the larger units may soon surpass room units in popularity, leaving the latter to serve only in existing houses and apartments. There is no question but that a well-designed central system can serve a home cheaper and more quietly than the required number of window units. The matter of appearance is also a prime consideration.

Except in very special cases, the home purchaser or builder cannot afford to include equipment which is difficult to obtain or systems that require special engineering design. These essentials of economy—availability and simplicity of design and installation—are rapidly being met. It now costs less than half the price of an automobile to install air conditioning in the average home. The seasonal cost of cooling is often less than $100. Cooling units combined with air furnaces or easily adapted to parallel use are making their appearance. Small cooling towers and air-cooled condensers may be obtained to solve the water-use problem. The bugaboo of difficult engineering design has been dispelled by the publication of *Manual 11* of the National Warm Air Heating and Air Conditioning Association. It is called *The Design and Installation of Summer Air Conditioning for New and Existing Residences.* The engineering design has been simplified to put it within the purchasable reach of the average home owner and to make it understandable by the builder and heating contractor. Planning the home for minimum heat gain, selecting equipment, and sizing the ducts and registers are subjects that have been standardized by this valuable new reference.

planning for minimum heat gain

The design of any heating or cooling system truly begins with the selection of a site, orientation of the house, and the design of the house itself. A home well arranged for minimum heat loss during the winter may easily be very poor at resisting the entrance of heat during the summer. Reduction of heat loss is quite simple and involves only double glazing, improving insulation, and minimizing air infiltration. Control of heat gain is more complex and may have a greater effect on the architectural design. The critical heat loss is usually computed on the basis of the inside and outside temperature difference without credit for the effect of solar heat or the gain from people or equipment. Critical heat gain for cooling load, however, *must* include the adverse effect of sun, people, and equipment. It must include also the reradiating effect of surfaces already heated for many hours. One must therefore consider that the worst winter condition occurs at night, and the worst summer condition in the late afternoon when all surfaces have been sun-heated.

Of the several items of heat gain—namely transmission due to temperature difference, heat emission of people, humidity gain, and sun effect—the last item is by far the greatest problem and will be observed to dominate the design. A simple consideration of sun effect will quickly establish design criteria. It can be seen that the direct sun intensities on an east wall in the morning, roof at noon, and west wall in the late afternoon are respectively 211, 290, and 211 Btu/hr/sq ft *(Figure 1)*. Glass permits practically all of these heat units to enter the house. Insulated frame construction, on the other hand, will reduce these transmissions to about 2, 4, and 2 Btu/hr/sq ft or about 1/100 of the sun-through-glass gain. Thus glass in the east and west walls and roof, which advantageously borrows sun heat in the winter, is virtually ruled out when summer operation is considered. It is possible, however, to retain the usual south glass if it is protected by a roof overhang. This feature, which admits great and beneficial heat gain in winter through unshaded glass, admits only 33 Btu/hr/sq ft in summer through shaded glass. Glass in the north also brings only a slight addition to the load. There are many other precautions against heat gain but the one just discussed is the most important. The interposition of glass between the sun orbit and the interior of the house by placing it on the east, roof, or west is the greatest single error in planning for minimum cooling load. If the use of glass in any of these positions is unavoidable, then placing it in full shade from the outside will reduce the heat gain by about 70 percent.

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* *Professor of Architecture, Pratt Institute, Brooklyn, New York.*

Aspiration to perfect planning from the engineer's point of view will suggest the following additional items of heat-gain reduction.

(1) Double glazing which reduces the heat transmission through shaded single glass, by about 50 percent.

(2) No direct sun on any glass.

(3) Full insulation in all frame structure, including roof.

(4) Use of very thick masonry walls which provide a 12-hr time lag in heat transmission.

(5) Every possible surface of the house to be placed in the summer shade of deciduous trees (which will admit sun in winter).

(6) Outside shades, baffles, or blinds to protect glass from sun. These reduce the gain 70 percent while inside shades or blinds decrease it only 10 to 30 percent.

(7) Real ventilation of double-surface roofs, not just a few small holes for air circulation. Insulation should be in the lower surface.

(8) No operable windows; house fully sealed winter and summer. This prevents the uncontrolled entrance by infiltration of warm air and humidity. Freshness can be maintained by adding a controlled portion of 25 percent fresh air to the air circulated. Exhaust fans in baths and kitchens eliminate excessive humidity.

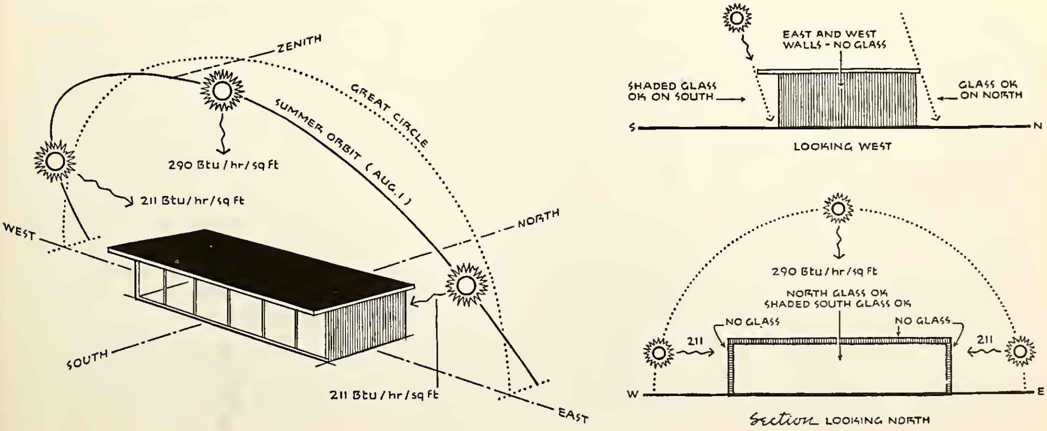
(9) Vapor barriers in all surfaces, including floors separating crawl spaces from living areas above. This reduces the humidity load.

(10) Continuous operation of the cooling unit to prevent the carry-over or flywheel effect of surfaces previously heated, and to prevent the accumulation of humidity in dead spots caused by still air.

The concept of air conditioning as an adjunct, cooling only part of the house or turned on only occasionally, seems to be giving way finally to the acceptance of full environment control both summer and winter. Owners who have lived in fully air-conditioned homes for 10 years or more report very favorably on the advantages. They like the continuous air circulation, the controlled addition of outside fresh air, the reduction of humidity in summer, and its increase in winter. The tendency is to keep the system operating at all times for air circulation and to add the operation of heating or cooling as needed. Desirable results are dust-free rooms, little cleaning needed for drapes and upholstery, and fewer colds. Quietness is assured because street noises are muffled by double glazing and sealed construction. The cost of continuous operation is very little more than for intermittent use—and the performance of a system designed for full air conditioning is not good if it operates only part of the time.

The house-design changes for full air conditioning may affect our present design esthetics somewhat. There is no need, however, to sacrifice glass-to-the-south or the concept of indoor-outdoor living, except that it will be modified by a permanent glass division between rooms and outdoors. Breezes, now less essential, will have to be enjoyed on outside ter-

Figure 1—insulation against direct sunlight and the use of light colors are recommended for air-conditioned homes. (Values are approximate and for conditions on August 1 at 40 degrees north latitude.)



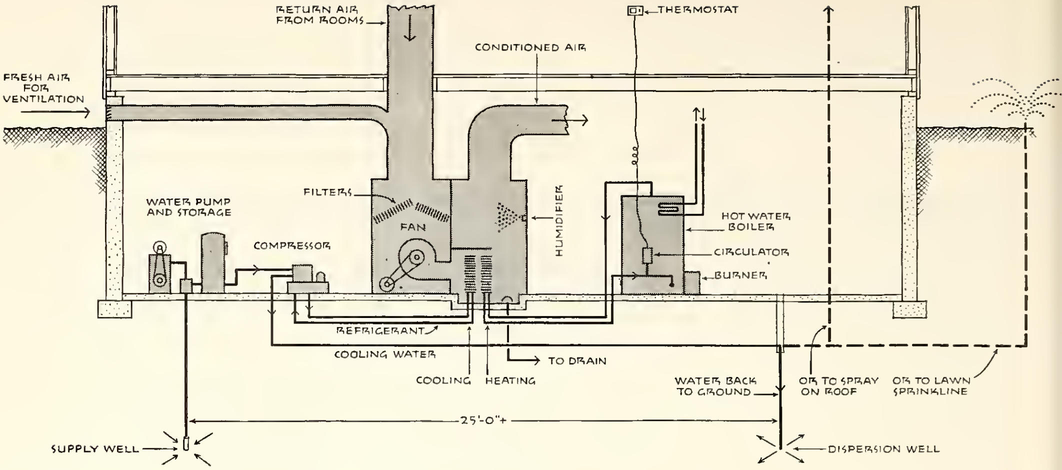


Figure 2—schematic layout of a complete system using a hot-water boiler.

races. The slight increase in cost of mechanical installation may be largely offset by construction savings such as the omission of all operable windows.

selection of the central unit

In planning for air conditioning it is presupposed that a ducted warm-air installation will be used for distribution. The combination of separate ducted-air-conditioning and a "wet" steam or hot-water radiator system is not economically feasible. The use of a hot-water boiler, however, is not impractical and offers many advantages. A scheme which has been used with great success is shown *(Figure 2)*. The hot-water boiler supplies water to a finned coil in the air unit. Winter and summer the boiler water is kept at 200 F by an aquastat which operates an oil burner or gas unit. This facilitates the year-round generation of domestic hot water. In winter the room thermostat turns on the water circulator which sends water to heat the air-unit coil. Air is delivered to the house at temperatures somewhat milder than in an air-furnace system. The fan runs full time but could be arranged to turn off for short periods if the furnace-bonnet temperature drops below a certain limit. This would prevent the circulation of low-temperature air which might be uncomfortable. A humidifier operated by a humidistat sprays warm water into the air stream.

Summer performance depends on the cooling coil which dehumidifies as part of its cooling function. Frequently the latent load (moisture to be condensed) is 30 to 40 percent of the entire load. This necessitates a plumbing drain which in this case also takes care of the excess water used in winter humidification. If reheating is needed after chilling out the moisture at a low dew point, the heating coil is available for the purpose. Fresh air is added through a duct from a grill in an outside wall. On the coldest winter days this may be shut off, if desired. The compressor in this case is cooled by well water, which is a good solution for this problem when ground water is plentiful. The well pump is started on call from a thermostatic heat element in the compressor. Several ways of disposing of the warm water are possible. It may be dispersed back into the ground, through another well not closer than about 25 ft. Lawn sprinklers may use it or it may be sent to a spray on a flat roof, which is a great aid in reducing the cooling load. The use of municipal water for cooling is generally prohibitive in cost.

Another solution to the central unit problem is shown *(Figure 3)*. The air furnace is tandem-connected to a package air conditioner of proper size for the load. Manually-operated splitter dampers change the air routing for summer or winter operation. Problems which are common to all air conditioning are: provision of a drain; periodic cleaning or replacement of filters; introduction of fresh air; and addition of moisture in winter by humidification. This system makes no provision for domestic hot water, which must be separately generated. For heat, the oil or gas burner responds to the thermostat. The fan operates whenever the warm air actuates the furnace-bonnet switch and until the air has cooled considerably following the turning off of the burner. Continuous operation is approached. In summer the fan will operate continuously for ventilation, circulating the cooled air when the thermostat actuates the refrigeration unit. This cooling unit is equipped with its own fan.

A combined unit, utilizing one fan with a damper to change the air stream from summer to winter operation, is most economical of space *(Figure 4)*. Even the compressor is an integral part of the package. It is merely necessary to connect the burner, humidifier, ducts, drain, and the air-cooled condenser. In this illustration, the compressor cooling problem is handled by an air-cooling unit which may be located in the breezeway or above a flat roof. In the larger sizes, air-conditioning units require cooling in the form of a water tower operating on the principle of the evaporation of some water. In this case, a make-up water connection will be needed. The air-cooled condenser

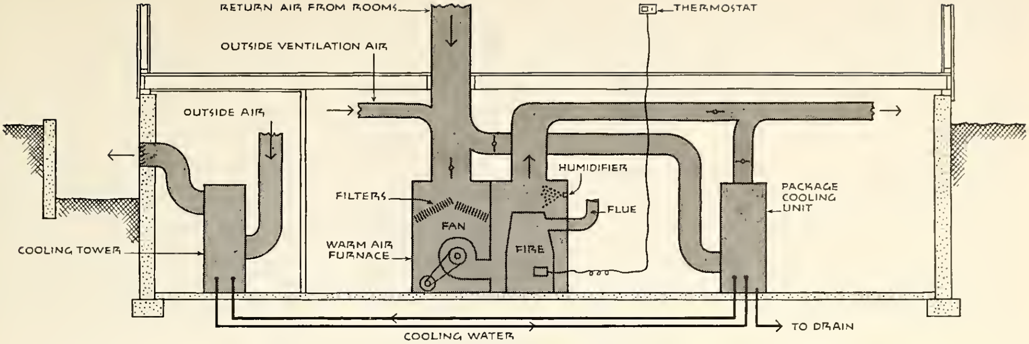


Figure 3—diagram of system using warm-air furnace and package cooling unit.

or the water tower must be placed in exposed positions. The combined unit is now available with cooling in 2- and 3-ton sizes. Since 1 ton of refrigeration represents a cooling rate of 12,000 Btu/hr, these units will carry a heat-gain load of 24,000 to 36,000 Btu/hr. This is appropriate cooling for the average house in the middle latitudes of the United States. Six-ton sizes will be available soon. The smaller units come with air-cooled condensers, which are much neater than cooling towers. The heating sections of these units must be correctly sized. In the middle latitudes, the average house may have an hourly winter heat loss of about twice the rate of summer heat gain. Thus the heater will have to have about twice the power of the cooling apparatus.

air distribution

In designing a joint installation to heat and cool by air, it is necessary to reappraise the principles that affect air distribution in cooling and in heating systems separately. In this way, it is possible that the important features of each may be retained and intelligent compromises made when necessary.

The old "gravity" warm-air system made a practice of delivering warm air at low points from interior walls. From these locations the warm air rose. Short ducts served these interior locations. Return air was collected at a few cool loca-

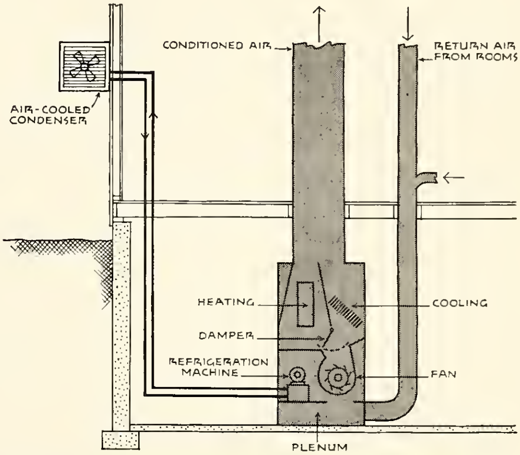
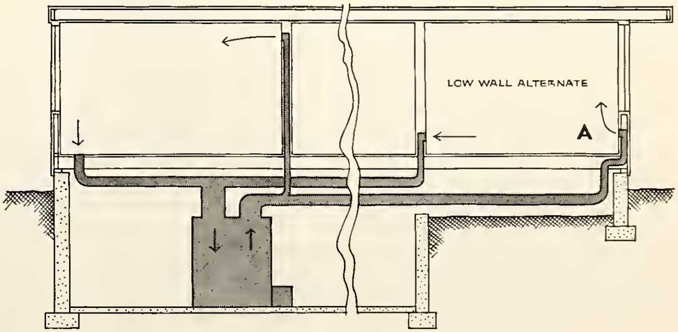


Figure 4—this unit combines heating and cooling functions.

Figure 5—conventional distribution (left); *newer low-wall delivery beneath window* (right) *"fans out" air stream flat against the wall.*



tions at the outside walls. With the development of forced warm air, the delivery registers were raised to high wall positions so that the air delivered now at high speed would not impinge on the occupants. Registers were still at interior walls and cool-air collection at points below windows *(Figure 5)*. Distribution is better because the warm air can be blown across the room toward the cool exterior walls. Force thus "pulls" the air to the return grills, instead of waiting until it cools sufficiently to drop. Recent use of much glass has pointed up the shortcomings of discharging warm air at warm interior walls and allowing the exterior walls to remain cool because of the proximity of cool return air.

The reversal of this conventional distribution is now gaining favor *(Figure 7)*. Warm air blown upward along the window surfaces immediately counteracts the coldness of the outside walls. By the time the air starts across the room to the return grill, it is milder in temperature than if it had started from an interior wall register without the tempering effect of the cold wall. Low-wall delivery *(Figure 5-A)* used in the older system is also possible in the new one, provided the register "fans out" the air stream flat against the wall and if it is placed below windows.

It will be noted that all of these methods deliver air parallel and close to the ceiling or an outside wall and away from people. All of the foregoing comments about improved distribution of warm air apply with equal importance to the routing of cooled air. Upward discharge along outside windows walls has the same effect in creating a uniform, mild temperature in occupied space. Low-temperature air is even more uncomfortable than warm air when it is directed toward one in a stream. The dual use of air for heating and cooling has brought with it a device for air distribution which originated with air conditioning. This is the ceiling diffuser which is still used by preference over wall registers in the best commercial and industrial air-conditioning practice. It is new and very effective in residential design. Low-cost, efficient units have been developed. They distribute *(Figure 6)* to a full perimeter which is about four times the scope of a wall register. Within two ft, and thus above the heads of people, they blend air temperature to a degree close to the room average. They accomplish perhaps the best dispersion of any distribution system. By the use of ceiling diffusers, a short-radial duct system from a central plenum can be used in the attic. In many cases this will be on the side of economy. Rapid heat loss which tends to reduce the inside temperature of glass walls also affects greatly the surface temperature of slabs on grade. Research has shown that any heating system that does not directly warm slabs and slab perimeters will permit floor temperatures so cool as to be uncomfortable. These temperatures, sometimes as low as 60 F may be raised to 85 F by schemes such as those shown *(Figure 7)*. Besides the improvement in the heating cycle, it is obvious that when cooled, these floors can form radiant-cooling surfaces. The presence of these cool surfaces, which improves the comfort of the space, makes it necessary to keep the dew point of the air below the temperature of the slab. In order to prevent condensation, the dew point of the air should be kept at about 60 F or lower, if the slab is about 65 F.

size of ducts and registers

While the heat gain in a room may be only about one-half the heat loss, the required delivery of cool air in cubic feet per minute is usually greater than for warm air in winter. The reason is that cooled air is delivered at only 20 degrees lower than room temperature while warm air is often delivered at a temperature 80 degrees higher than room temperature. More cooled air must be supplied at the smaller temperature differential. This requires that the ducts and registers be sized for cooling operation and perhaps dampered down for winter use. This is one reason why the adaption of existing heating systems to the addition of cooling is difficult. The ducts are generally inadequate. The modern trend is to have a number of small standardized supplies for each room, one or several of which can be turned off or dampered down in winter.

Occupancy of a closed house with continuous circulation summer and winter requires that the air motion be as imperceptible as possible. Consequently diffusers, air-base distribution, or numerous discharge registers are indicated. Saving in this phase will inevitably lead to discomfort. An analogy can be made to lighting. Intensity for room illumination could be had by hanging a naked 200-w bulb in the center of the ceiling. Yet a more subtle lighting is generally chosen, using dispersed sources of lesser intensity. It would be just as inefficient to attempt to blast into a room through one register sufficient air for heating or cooling needs.

There is another determining factor in the choice of the size of supply ducts and registers. The heat gain of an individual room varies during the day according to the location of the sun. The ducts and registers for a room must be chosen for the time when the room heat gain is greatest even if this is different from the time when the over-all heat gain to the house is greatest.

size and operation of the unit

The proper capacity of the unit is not the sum of the critical heat gains of the several rooms. Each room has its maximum gain at a different time of the day. The central unit which cools all rooms carries the maximum cooling to only one room at a time, the other rooms adding somewhat less than their maximum gain. So the over-all heat gain of the house is computed as though there were no room divisions and for the time of day when the house as a unit experiences its greatest heat gain. This is generally about 4 p.m., after the house has been exposed to the sun all day and the air temperature outside of the house still remains critically high.

In the interest of continuous operation, it is important not to oversize the cooling unit. By keeping it small, it will run most of the time and so reduce the humidity that might otherwise accumulate between periods of operation. By continuous cooling, even during the night, the house can be maintained at a lower thermal content with correspondingly lower inside surface temperatures. This flywheel effect provides a lower mean-radiant temperature of walls, ceilings, and floors. This effects radiant cooling during short periods *(Figure 8)* when the inside air temperature might rise slightly above its design value. With a cool environment the rise in air temperature may never be noticed. On the other hand, if the house were permitted to heat up during most of the day and night, even a larger unit might fail to overcome by low room temperature the warm effect of the heated surfaces. Homes, unlike public buildings, are not regularly subject to critical loads due to many people and so do not require large units for short duration cooling. A small unit operating continuously to keep house surface temperatures low is the proper choice.

A prominent heating engineer tells an anecdote about the "flywheel" effect in the heating of a church. The system was designed to keep the church at a comfortable temperature on Sunday, provided it was kept partially heated all week. In operation the design was justified. Later, in an effort to save fuel, the heat was turned off completely during the week. Thereafter, no amount of heat on Sunday could keep the congregation warm because of the chilling effect of the cold masonry walls. In the application of this principle to the air conditioning of homes, there is no attempt to cool people by supplying cool air during the hottest part of the day but rather to keep a house cooled to provide a low-temperature radiant environment for the occupants. In this aim a small unit is more effective than a large one.

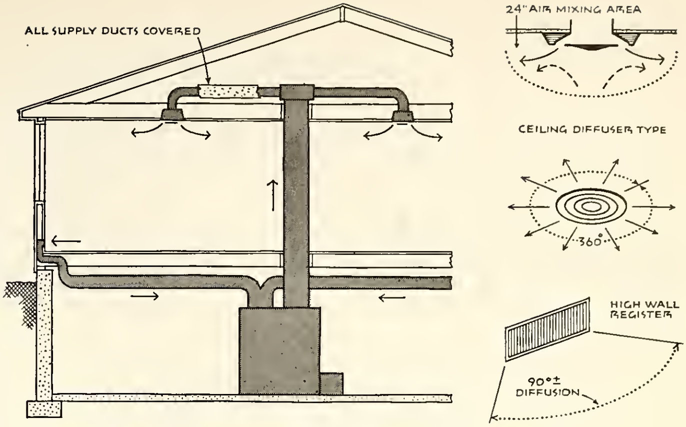


Figure 6—ceiling diffusers have advantages for residences.

Figure 7—perimeter or cavity-slab distribution gives radiant effect.

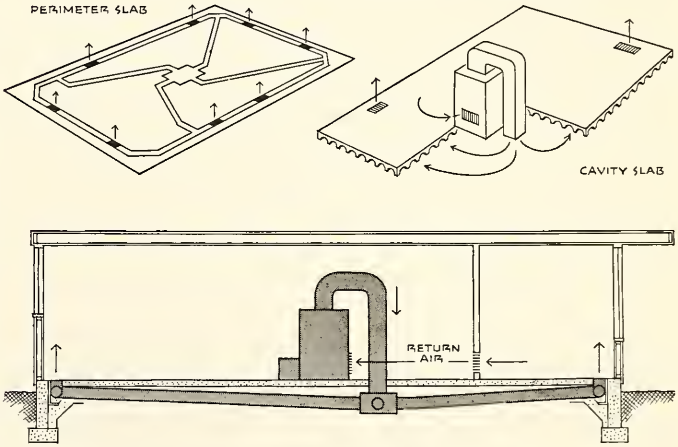
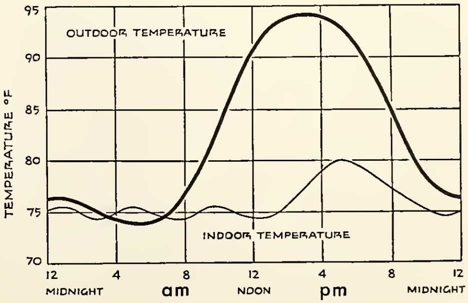


Figure 8—24-hr operation cycle, thermostat 75 F, differential 15 degrees.



Heating Design for Future Cooling

BY ROBERT H. EMERICK*

When a client tells his architect, "Please design my new home for *future* summer cooling," the problems created can be more than strictly technical. They can involve, for example, the question of extra fees.

To illustrate, an engineer is quite likely to point out that allowing for summer cooling at some future date obliges him to compute the summer load, to locate the ultimate plant, at least tentatively, and to particularize his specification beyond the normal requirements for heating alone. He might even feel compelled to make rough sketches of his dual-purpose design in order to verify the accuracy of the pattern.

Usually his first reaction in such circumstances is to ask who will pay for the extra engineering. As this question is disturbing to all concerned, the writer has developed a method for determining the summer load with sufficient accuracy to meet all initial design requirements, and yet avoid the expense of a detailed engineering analysis. To see the procedure in action, we must tabulate first the factors that shape a cooling design. They are:

(1) Sensible heat that enters the building through the walls, roof, windows, etc.

(2) Solar heat, impinging on the structure, with perhaps some direct rays entering certain rooms through the window glass.

(3) Sensible heat emitted by the room occupants. Each human being releases approximately 180 Btu per hour when seated and at rest.

(4) Latent heat from the room occupants, with an approximate value of 100 Btu per person per hour. This heat is present in the form of water vapor, rejected in exhaling, and as moisture evaporated from the skin.

(5) Sensible heat from lights.

Sensible Heat Through Structure

In order to achieve an estimate of summer cooling, we must develop approximate values for each of these factors and in the details of normal calculating this is a very lengthy procedure. Our short cut method starts with the sensible heat that enters the building. Happily, this answer is easy to come by since the building cooling load bears a direct relationship to the heating load. Both of these loads are calculated with the same set of heat-transmission coefficients so that only the temperature difference between winter and summer conditions sets the results apart. Thus, with a computed heating load already in hand, we need merely pick up a slide rule and with two settings of the runner, determine the sensible heat gain through the structure. The formula is:

$$S = \frac{W \times td_2}{td_1}$$

S = Summer sensible heat load by transmission, Btu/hr

W = Winter sensible heat load by transmission, Btu/hr

td_1 = Temperature difference winter, degrees F

td_2 = Temperature difference summer, degrees F

To illustrate, assume we have a living room that shows a heating load of 20,000 Btu per hour when calculated on a temperature differential of 0F — 74F, then the summer cooling for a temperature difference of 80F — 95F will be $\frac{20,000 \times 15}{74}$ or 4054 Btu per hour.

This transmission load is merely the first factor but it provides us with a basis on which to erect values for the solar, fresh air, and latent heat loads, each of which is computed by a system of ratios which are themselves subject to variations in the light of particular conditions.

Solar Load

The first ratio concerns the solar load. Sunlight calculations are always generously leavened with judgment, even if we endeavor to reach a scientific value based on latitude, sky reflections, solar angles, etc. This must be so because a single cloud at the critical hour, or the fall of a tree in a storm, or the carelessness of a maid in failing to wash windows has the power to invalidate these scientific estimates, not merely for one season, but again and again. Consequently, an analysis of many relationships between the solar load and the building transmission load indicates to this writer the reasonableness of assuming the solar load to be 1¼ times the transmission value, provided this fraction is used as the *basis for further consideration.*

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* *Consulting Mechanical Engineer, North Charleston, S. C.*

Determination of Total Cooling Load

Room	Heating Btu/hr	Cooling bldg. factor td_2/td_1 Btu/hr	Human load Btu/hr	Solar* load Btu/hr	Lighting load Btu/hr	Total load Btu/hr
Living	20,000	4054	2160	5068	——	11,282
Dining	10,000	2027	1440	2534	——	6,001
Bed. #1	7,000	1419	360	1419	——	3,198
Kitchen	12,000	2433	360	2433	500†	5,726
Bath. #1	1,500	304	180	380	——	864
Bath. #2	1,500	304	180	——	200	684
Bed. #2	5,500	1115	180	——	200	1,495
						29,250

* Solar load has been sized on the 1¼ fraction or on the 100 percent basis to demonstrate application of the principle.

† The kitchen load for lighting should be expanded to include the load from cooking appliances.

Note: Total air circulated = 29,250 x 0.0585 = 1711 cfm.

By further consideration is meant the common sense readiness to increase the fraction if the room being weighed is heavily exposed to the sun, and conversely, to decrease it in cases of extensive shading. The range suggested is 5 percent for minimum exposures and up to 175 percent for maximum exposures.

The Human Load

For the sensible and latent factors of the human load some understanding of the kind of people who will occupy this house will be our best guide. For example, suppose there are sociable people and they are likely to enjoy afternoon bridge or evening canasta. We therefore study the dimensions of the living room and assume it will accommodate X number of card tables. If we then allow four persons to each table, we can approximate the number of individuals who will produce 180 Btu per hour each of sensible heat. The total, of course, becomes the expected human load for that room. We do the same thing for the bedrooms, allowing one or two persons in the room as the living habits of the family suggest to be likely.

The latent heat created by these people will not affect duct design which is the outstanding structural problem when allowing for future cooling, but it must be included when sizing the machinery. How this is done will be discussed in the later paragraphs on the sizing determinations for the cooling compressors. Meanwhile, we can safely neglect it.

Lighting Loads

Our final factor, the burden which night lighting places on the cooling system, need only be considered in those rooms which do not receive sunlight. The reason is that even a small hourly solar impress tends to approximate, and often exceeds, the output of Btu from the night lighting system. In addition, as further compensation for the evening, the building transmission load usually falls steadily after sunset. Our cooling design peak, therefore, is likely to occur in the late afternoon, and we should include those lights which might be turned on at that time, perhaps in heavily-shaded rooms.

assembling a useful answer

Since the basic responsibility in the problem was to design a winter heating system and we have the Btu for such a system room by room, the cooling burden is quickly determined if we follow the table (*top of page*), filling it in as appropriate.

While we now have a dependable approximation of the cooling load, room by room, the answer we really need for sizing the ducts is the cubic feet of air per minute. This determination, in a detailed engineering analysis, involves the use of psychrometric charts and careful recirculation calculations but for our present purpose, the procedure requires but a few moments and a slide rule. The steps are these:

(1) We assume a temperature differential between the air leaving the cooler and the air in the cooled room. Experience has shown 16 degrees to be a good average (64 F and 80 F in this case), although some designers have used 20 degrees without complaint.

(2) We multiply the temperature difference by 0.24, which is the specific heat of air, and observe that each pound of the cooler discharge will pick up 16 x 0.24, or 3.84 Btu.

(3) One other item is needed, in this example the volume of air at 64 F, and the standard tables show its value to be 13.47 cubic feet per pound.

(4) All the data are now set down in an equation designed to produce the desired information in cubic feet of cooling air per minute. The solution is achieved with a few moves on the slide rule. Here is the way it works out with the living room figures:

$$\frac{11{,}282\ (\text{Btu/hr}) \times 13.47\ (\text{cu ft/lb})}{3.84\ (\text{Btu/lb}) \times 60\ (\text{min/hr})} = 660 \text{ cu ft/min}$$

These steps have been demonstrated in some detail in order to make clear the reasons for doing what we do. In practice. we actually shorten the procedure by developing a multiplying factor which is applied directly to the cooling load for each room. This factor is simply the solution of the foregoing equation *except for the room load in Btu per hour*. In this case it would be: $\frac{13.47}{3.84 \times 60} = 0.0585$; and, 11,282 x 0.0585 = 660 cfm (living room); 6001 x 0.0585 = 351 cfm (dining room); 3198 x 0.0585 = 187 cfm (bedroom #1). Each room is considered in the same fashion.

Arriving at a useful answer, therefore, requires us to complete two journeys by slide rule. The first, starting from the winter heater load, ends with the determination of the summer cooling load. By means of the second, we convert the summer cooling load to cubic feet of air per minute. The time to complete both journeys should not take an engineer longer than a single hour.

sizing the ducts

The importance of knowing the volume of cooling air that a room requires lies in the fact that more air is needed for cooling than for heating. If we size a duct for cooling, therefore, we can expect it to accommodate warming air most satisfactorily but we cannot speak so confidently of the results when this design basis is reversed.

The preponderance of air on the cooling cycle is made necessary for the comparatively small number of Btu picked up by each pound of the cooler discharge. In the example discussed these totaled 3.84, whereas heating air with an assumed register discharge of 150 F bears 150 F = 74 F x 0.24 = 18.24 Btu.

At 150 F a pound of dry air occupies 15.37 cubic feet and if we substitute this volume, together with the Btu value in the simplified formula, the multiplier comes out to:

$$\frac{15.37}{18.24 \times 60} = 0.0145 \text{ (approximately).}$$

Applying this multiplier against the living room winter load of 20,000 Btu per hour produces a calculated air movement of 290 cfm. Since this is less than half the requirements for the summer cycle, the controlling effect of the cooling operation is obvious.

Our cooling calculations, therefore, will be the figures to be used for duct design when making allowance for summer cooling and the specifications and drawings will present these facts to the contractor. In order to hold down costs, summer velocities may be set at the top acceptable limit; on the heating cycle the oversize of the heating ducts will then be less marked.

size of the cooling machinery

The architect who has provided a heater room in his plan always hopes that the summer-cooling plant can be squeezed into the same space. One possibility is to use a suspended type of horizontal heater, then when the future becomes the present and the owner is prepared to install his cooling compressor, the floor space beneath the heater is available. As an alternative, the suspended heater might be mounted under the roof in the carport, garage, or in the attic above the house proper. Any of these alternatives will increase the cost of the duct system and complicate the arrangement.

The size of the cooling plant is not the simple summation of the cooling loads as we have already observed them. Fresh-air make-up, which may be established at any desired volume but usually is projected from 10 to 15 percent of the total air circulated, introduces a substantial load, both sensible and latent. Compensating to some extent is the factor of diversity, which means that the maximum load is not the same for all areas of the house simultaneously.

To observe the relative effect of the fresh-air intake on the size of the plant, suppose we assume a 10 percent make-up based on the total air circulated to the seven rooms already indentified on the load chart. This means 10 percent of 1711 cubic feet per minute—approximately 171 cfm.

Converting into pounds, we have 171 ÷ 13.47 (the volume of air at 64 F) or 12.69 pounds per minute. These 12.69 pounds are brought in from the outside and their temperature, of course, is not 64 F but 95 F. Chilling them down these 31 degrees imposes a load on the cooling machine of 31 x 0.24, or 7.44 Btu per minute per pound. Thus, in one hour the sensible load alone is 5664 Btu.

The moisture in this incoming air is what imposes the major latent heat load on the machine for most residential installations, rather than the exhalations of the occupants. In this case, with an outdoor temperature of 95 F and 53 percent relative humidity (80 F wet bulb), a condition frequently encountered in many sections of the country, the lowering of the air's temperature to 64 F in the cooler squeezes out approximately 42 grains of water vapor from each pound. This figure is obtained from the psychrometric chart.

Since we are bringing in 12.69 pounds of fresh air each minute, at the end of an hour's operation $\frac{12.69 \times 42 \times 60}{7000 \text{ (grs/lb of water)}}$ equals about 4.57 pounds of water removed from the incoming fresh air in the cooler. While in the vapor state, this water represents an investment in heat of approximately 4570 Btu, since 1000 Btu are incorporated in the evaporation of one pound of water and all of these Btu must be spent in the cooler.

At this point we will consider the humidity created by the persons present in the house. Twelve bridge players, breathing water vapor into the air at a rate of about 700 grains of moisture per hour each, are producing a burden on the cooling machinery of 1200 Btu per hour, more or less, depending on the excitement of the game. Tabulating the fresh air and latent heat situation, all of which affects the sizing of the cooling machinery but not the room distributing system, we have:

(1) Fresh air sensible heat removed in cooler.......	5664 Btu
(2) Fresh air latent heat removed in cooler.........	4570 "
(3) Human latent heat removed in cooler.........	1200 "
Total	11,434 Btu

If we now add the 29,250 Btu per hour for the other cooling items previously calculated, the future allowance in machinery for this particular case totals 40,684 Btu per hour, or 3.4 tons of refrigeration.

This is the maximum gross load but it is not likely to occur because of the influence of diversity. Incidentally, to obtain the greatest advantage through diversity operating, a rather complete system of controls is needed and the average residence lacks this benefit. Therefore, a diversity allowance factor of no less than 90 percent is recommended by this writer as a general safety rule, since any more optimistic allowance might result in an undersized installation.

sizing by short cuts

Humidity calculations along the psychrometric highways involve considerable time; consequently, doing them is not pleasing to an engineer who sees no extra pay for his work. However, there does exist a byway to the same end, its foundation secure on what we already know, and it is very easy and quick to follow. Here it is:

Step 1: X number of persons x 100 Btu/hr = Total human latent heat
Step 2: Total human latent heat x 4 = Latent heat in fresh air
Step 3: Building transmission load x percent fresh air x t_1/t_2 = Fresh air sensible heat
Step 4: Add 1, 2, & 3 to building transmission load = Gross machinery load
Step 5: Gross machinery load x diversity = Net machinery load. This is the proper size.

Most of these steps are obvious but some explanation of 2 and 3 is in order. First, there is an indirect relationship between the number of persons in a building and the volume of fresh air needed. As in the case of the solar conclusions, analysis of numerous jobs suggests that a 4 to 1 ratio is a good average starting point. Individual practitioners referring to their own experiences may desire to change it, either up or down.

The fresh air sensible heat load is developed by means of a direct ratio between the *outside* temperature-to-cooler differential and the *inside* temperature-to-cooler differential. Thus t_1 is, in this case, 31 degrees and t_2 is 16 degrees; $t_1/t_2 = 1.94$ approximately. Knowing the total inside sensible load as we do, multiplying by the 10 percent of outside air and then by the temperature differential ratio becomes a clear road to the outside load's value.

Translating these ideas into a working demonstration of the short cut produces the following results:

Step 1: 12 persons x 100 Btu/hr = 1200 Btu/hr
Step 2: 1200 x 4 = 4800 Btu/hr
Step 3: 29,250 x .10 x 2 (approx.) = 5850 Btu/hr
Step 4: 29,250 + Steps 1, 2, and 3 = 41,100 Btu/hr
Step 5: 41,100 x .90 diversity = 36,990 Btu/hr
Tonnage = 3.09 tons of refrigeration.

Residential refrigeration machines are fairly well standardized at 2, 3, and 5 tons (or horsepower); consequently in this case we would recommend a 3-ton machine. For in-between sizes, judgment must be exercised with particular care being taken not to undersize. A wise memory is one that tells us to consider the reduction in capacity that follows the appearance of algae and scale in the condensing system and reminds us that machinery efficiency naturally decreases with time.

space for the physical installation

With the size of the cooling machinery determined, space must be found in which to station it. In a normal arrangement, the heater is set at one side of the heater room, thereby leaving space for the cabinet cooler. Unfortunately, this does not solve the whole problem. Condensing equipment remains to be accommodated somewhere. A cooling tower on the roof is not an admirable sight and if we set it on the ground instead, neighborhood children will delight in throwing toys, stones, and pet rabbits into its watery cascades.

The alternative is to place it in the heater room with duct connections for circulating the outside air which serves it. But, is there space for this rain-closet, which is more than 5 ft high, and occupies a floor area of about 2 ft by 2 ft? If not, the architect faces an irritating problem. Possibly the house plans are drawn before the request to provide for future cooling comes in and thus, revisions of the design can be quite costly.

For self-protection, architects should make a point of discussing possible future cooling with their clients at the very beginning of a project. Waiting for the client to bring up the subject is a mistake.

Occasionally, local water supplies are plentiful and cheap and in those circumstances the client might be willing to condense the refrigerant vapor with water that runs thereafter to waste. Space requirements are benefited by the omission of the evaporative condenser but these instances are the exception. Incidentally, a 3-ton machine will use about 5 gallons of condensing water, more or less, every minute it operates and this quantity can create municipal problems. To illustrate, some communities will not permit the cooling water to be discharged into the house sewer because of the extra burden this water places on the sewage-disposal plant. From the supply standpoint, areas contending with critical water shortages or overloaded distribution systems are almost certain to deny water from their lines to air-conditioning condensers.

the register situation

In one-story houses, conventional practice locates the warm-air registers high in the wall. This location needs no change for summer cooling as the point of cold-air discharge is properly high above the floor.

With multistory buildings, the best positions for the warm and cold registers are in conflict. Due to the building's stack effect, which is a way of acknowledging the nature of warm air to rise, heating registers produce best results when set in baseboards, or nearly that low. However, cold blasts emerging from these same low registers and impinging on the ankles of the building occupants will be appreciated by no one. The treatment of this situation is to go up with the cold-air registers, to extend the wall stacks to high wall positions, or alternatively to carry the ducts to ceiling diffusers.

Under some conditions, ceiling diffusers may prove satisfactory for both cold- and warm-air service but the design of the diffuser is critical and a mischoice produces alternate cold or hot blasts, depending on the season of the year.

Allowing for summer cooling, therefore, means providing extended wall stacks or rearranging ducts to serve ceiling outlets at the time the heating system is installed, even if these extra lengths of duct and extra registers will not be used for years, perhaps never. The engineer will benefit a little by the extra construction cost if his fee is based on a percentage of the job and he will not, therefore, grumble very persistently about it.

future cooling and wet heat

If the new house is to be heated by either steam or forced-circulation hot water, we have two basic alternatives to consider for future summer cooling allowances.

First of these is the obvious scheme of employing two entirely unrelated systems. The heating system is simply a conventional layout of steam or hot-water convectors and the summer cooling is an equally conventional design of forced-circulation chilled air, distributed through ducts.

This arrangement of two unrelated systems is perhaps suggested most often by the client because this is the way he sees it. As for the engineer, he is in exactly the same position he would occupy if the heating were to be accomplished by warm air. On the basis of his heating load, he applies the short cuts that develop for him the duct dimensions and the equipment sizes and he reports to the architect whether there is sufficient space for everything in the heater room. There is even some additional cost of installation for the ducts, bringing a modest increase to the design fee.

The second alternative, unfortunately, is one over which our short cuts have no power. In this scheme, each room enjoys a special type of conditioner cabinet, wherein piping elements are supplied with hot water during the winter, and cold water during the summer. Behind the elements is a fan, so that air circulation through the cabinet and over the elements is positive, and each cabinet is connected to the outdoors for fresh-air intake as desired.

Since all the piping must be installed to supply heating water, there is nothing to postpone for future cooling except the cooling machinery itself which chills the water for summer circulation, plus a fairly complex arrangement of three-way valves with their automatic controls. A system of this kind requires complete designing from the start and both the architect and the engineer are entitled to request the entire fee, whether the summer equipment goes into the new building now or never.

This system is intended primarily for hotels and apartment houses and is rarely justified for anything smaller, at least for the present.

summing up

The client who asks for a heating system that allows for future cooling is taking cognizance of a trend. By means of the short-cut methods described, the designing engineer can determine, at a negligible cost to himself, the size of the ducts for the cooling cycle and the size of the cooling machinery.

The figures so developed are not exact but for the purpose intended they are well within practical tolerances. To enjoy the maximum of accuracy for any given job and location, users of these short-cut methods should modify the ratios and basic values to meet their own experienced estimates for the solar exposure, fresh air make-up, persons present, and so on.

The normal time-labor investment, from start to satisfactory answer, is less than two man hours.

Odor in Air Conditioning Systems

BY KEVIN B. MAGEE*

From the inception of air conditioning, one problem has been the insurance of obtaining pure air for the conditioned space in the presence of innumerable foreign substances prevalent in the air around it. Air *quantity* remains static over most of the earth's surface; all *quality* varies extremely. "Fresh" air is seldom fresh in the true sense of the word, particularly in cities and industrial areas. Practically all air contains more or less adulterants in solid or gaseous form, sometimes even to an extent hazardous to health.[1] The "poison fogs" suddenly and unexpectedly permeating industrial regions and the resultant hospitalization of its victims are an all too recent reminder.

An even more perplexing problem has been the *maintenance* of proper air quality within conditioned occupied enclosures in the face of gaseous and particulate impurities continuously generated and expelled by the occupants and their habits and services—dust and bacteria, body emanations, tobacco smoke, cosmetics, food and cooking, liquors, painted surfaces, furnishings, putrefaction, detergents, and numerous other contributions.[2] Most of those that are gaseous are manifested as odors.

Despite continuing technological progress in air conditioning in general, its advancement has been primarily in the direction of thermodynamics and psychrometrics—in the control of temperature and humidity. In other words, the emphasis has been and still is on thermal comfort. Man's equally vital fourth sense—that of smell—has been seriously neglected. This paradox is revealed in the latest definition of "air conditioning" from the official "Guide" of the American Society of Heating and Ventilating Engineers, reading "The simultaneous control of all, *or at least the first three of* these factors . . . of the atmosphere . . . temperature, humidity, motion, distribution, dust, bacteria, odors, and toxic gases . . ." Yet the remaining factors are every bit as important to human comfort and health as are the first three. No one today would seriously consider an air-conditioning installation without means for filtering out dust from the air to be breathed; yet harmful or, at best, annoying vapors are permitted to pass without restriction through these same filters, resulting in discomfort and in some instances actual distress.

With the gradual recognition of the importance of controlling odors and gaseous impurities in occupied spaces, there has appeared a profusion of air "purifiers"—perfuming agents, odor eliminators, ozonaters, ionizers, aerosols. These range from bottles of liquids, with or without wicks, sold in grocery stores, to equipment designed to vaporize them into the air circulated by air-conditioning systems. Most of these substances, however introduced, are either masking agents, i.e., they permeate the space with a stronger and presumably more agreeable odor, or contain counterirritants to accelerate fatigue of the olfactory nerves or even deaden or anesthetize the olfactory sense so that it is incapable of detecting either the masking or offending odors.

Although much study and experimentation has been devoted to the physiological effects of ozone (O_3) to determine its over-all value as an air purifier, the results have been inconclusive or negative.[3] Nevertheless, because ozone *in sufficient strength* will neutralize certain gases and vapors by oxidation it was for many years regarded as an odor eliminator, resulting in the development and application of electrical ozone generators and so-called ionizers to air-conditioning systems. However, the value of ozone for odor control in occupied spaces has been subject to serious criticism because of its inherent toxicity and the fact that, unless applied in toxic concentration, its oxidizing effectiveness is limited or nil. In dilute concentraton its effect, because of its own characteristic pungency, is simply one of masking plus to some extent narcosis of the olfactory nerve.**

Toxicologically, ozone in quite low concentrations (0.1 to 1 PPM) is a powerful irritant to the mucous membranes of the respiratory organs; constant exposure to relatively high concentrations (5 to 10 PPM) can result in pneumonia, lung congestion, and edema. The irritation threshold is generally around 0.05 PPM which, though not considered detrimental to health is, in the experience of the writer, ineffective in masking certain body odors, particularly under conditions of occupancy by persons of lower than average socio-economic status. At concentrations above 0.08 PPM, some office workers became ill and in one instance 22 per cent of the employees of a bank were sent home with headaches and similar indispositions after the installation of ozone equipment in the bank's air-conditioning system. It was found that concentrations above 0.05 PPM resulted in personnel absenteeism in direct proportion to the increase in ozone. Authoritative tests have established that body odors lack the ability to affect the ozone smell, resulting in a condition where the very effect striven for is nullified. In other words, the greater the concentration of body odor, the more ozone is required to mask the body odors and therefore the more noticeable the ozone odor becomes. Ozone is still used to some extent in refrigerated storage spaces not subject to sustained human occupancy, particularly in connection with the storage of whole eggs.[4] It cannot, however, be applied to the preservation of foods sensitive to rancidity, such as lard, butter, and other fats; even low concentrations of ozone hasten rancidity in these staples.

Basically, there are three methods in use today for the control of obnoxious odors and air-borne impurities in air conditioning. The first, and most elementary, is that of ventilation; namely, the continuous introduction into the occupied space of theoretically uncontaminated outdoor air. Even assuming such outdoor air is pure, it nevertheless imposes a direct charge on the conditioning capacity and is therefore costly. The second method involves masking accumulated, objectionable odors in the manner already reviewed and, whatever its merits, if any, consists of adding to rather than subtracting from the air-entrained impurities. The third method consists of extracting the odors from the contaminated air, filtering them out in much the same manner that air filters extract air-entrained dust. This method depends on the adsorption of the vaporous and gaseous impurities and the most powerful sorbent for this purpose, as well as the most practical in relative density and hardness, is activated carbon.

In its processed form, activated carbon contains a vast network of

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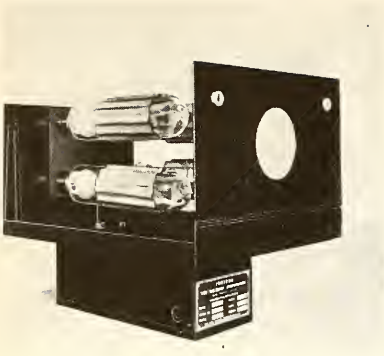
*Engineering Consultant to Industry, New York, N. Y.

** *Most practically produced ozone is still from devices which provide ozone of high possible nitric oxide contamination. It is possible, however, to produce ozone by the ionizing wavelengths of ultraviolet energy which, for all practical purposes, is free of oxides of nitrogen contamination and hence more suitable for odor control use within the limitations of all masking agents. Editor.*



Left — this ionizer was designed for installation in ventilating- or air-conditioning systems handling up to 12,000 cfm. Its size, 14" wide x 20" deep x 9" high permits the ionizer tubes to be located wholly within the ventilating duct — transformer and control apparatus are outside.

Right — two slightly different models of ozone producers. Operating on household current, three four-watt General Electric ozone lamps make the presence of odors less perceptible; they are suitable for volumes of up to 3000 cubic feet. Units should be mounted not lower than six and one-half feet from the floor in a way that shields the direct rays from the eyes.

Photos: courtesy of the Welsbach Corp. (left); and Atlas Consolidated Corp. (right).

extremely minute channels and submicroscopic pores within the structure of the material. The aggregate area of the active adsorbing surface in one pound of granular activated carbon has been estimated to be equivalent to about 140 acres. The ability of a given weight or quantity of carbon to adsorb the various gases present in the everyday atmosphere of an average city, both indoors and outdoors, is dependent upon the rate of flow of the air across the surfaces of the carbon, and the amount of carbon surface exposed to the air. The useful life of the carbon between reactivations is governed by the concentration of vaporous and gaseous impurities in the air to be treated, so that air containing relatively large quantities of impurities will obviously necessitate more frequent reactivation of the adsorptive medium than will less contaminated air.

From a purely physiological standpoint, an air-conditioned space requires surprisingly little outside, i.e., new air. Experiments conducted at the U. S. Naval Medical Research Institute,[5] for example, established that 1 cfm of chemically pure air per person will provide ample oxygen for an active worker and that 3.5 cfm per person will prevent the carbon dioxide from rising above the accepted limit of 1 percent. Ventilation requirements, i.e., adequate pure air to dilute internally generated and accumulating odors, on the other hand, may require anywhere from 10 to 50 or more cfm per occupant depending on conditions. In this connection, the reader is cautioned to regard the usually published recommendations or standards of ventilation requirements with reservations. Such data are invariably influenced by economic considerations and, therefore, represent minimum permissible rather than optimum values. In the conventional air-conditioning installation, the purchaser is paying for an excess of conditioning to an extent represented by the difference between heating and/or cooling the acceptable minimum of 3.5 cfm of outside air and the amount of outside air that must actually be supplied to maintain an odor-free indoor condition, usually about 15 percent of the total conditioning load plus, of course, a commensurate increase in operating costs.

In an air-conditioning installation it is usually advisable to introduce and condition sufficient outside air to maintain a positive pressure within the conditioned space to counteract infiltration of unconditioned air through door and window cracks. Therefore, the amount of air required for this purpose, generally at least the equivalent of 5 cfm per occupant, almost invariably exceeds that needed for purely physiological requirements. It will thus be apparent that the outside air can be reduced to a maximum of 5 cfm per person provided a sufficient volume of the recirculated, already conditioned air is adequately purified. It should be noted particularly that it is necessary to decontaminate only that percentage of the total air recirculated which, when added to the outside air supplied for pressurization, will provide the volume required for ventilation effect.[6] The actual quantity to be decontaminated will vary depending on the type and concentration of contaminants to be extracted. Likewise, the size of the adsorption equipment will be governed by service life or frequency of reactivation considered practical.

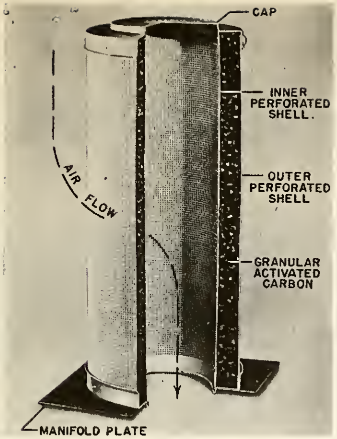
As an example to illustrate the saving in initial and operating costs through the application of air purification and recovery, consider a typical department store system requiring a total circulation of 100,000 cfm of which say 25,000 cfm should be ventilation effect and therefore conventionally outside air, the balance being recirculated. Assuming that the building can be adequately pressurized with 10,000 cfm, then the outside air can be reduced to this amount and 90,000 cfm recirculated, provided 15,000 of the 90,000 cfm is purified. As, in the mean temperature zone, every 1000 cfm of outside air supplied requires approximately 2.5 tons of installed refrigeration for cooling and 80,000 Btu per hour capacity of boiler and radiation equipment for heating, the saving in the hypothetical case cited would be 15 x 2.5 or 37½ tons of installed refrigeration and 15 x 80,000 or 1,200,000 Btu per hour of boiler and radiation capacity, conservatively equivalent at current costs to $8000 and $3000 respectively. Against these the installed cost of activated carbon air recovery equipment for a capacity of 15,000 cfm would not exceed $3000, resulting in a net capital saving of $8000.

Similarly, based on 1200 hours seasonal cooling at an average of one-half design load and one KW hour input per actual ton of refrigeration produced and a two cent per KW hour power rate, the reduction in cooling energy cost is 1200 x 37.5 x .5 x .02 or $250 per cooling season while, based on 2400 hours seasonal heating at an average of one-half design load of 0-70 degrees with 140,000 Btu oil at eight cents per gallon and 70 percent heating efficiency, the reduction in fuel cost is

$$\frac{2400 \times 15{,}000 \times 1.08 \times 35 \times .08}{140{,}000 \times .7}$$

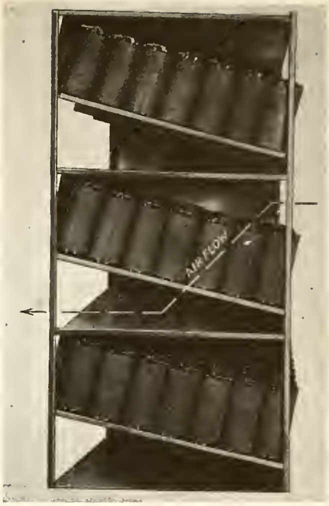
or roughly $1100 per heating season. Against this, again, the cost of reactivating the activated carbon recovery equipment will approximate $450 per year, resulting in an average net annual operating saving of $850.

The advantages of air purification by adsorption are that it neither adds anything to the air nor alters its chemical or ionic composition. Neither does it change either the air temperature or relative humidity be-



These photos illustrate the canister type of activated-carbon air-purification equipment. Left — typical canister is closed at top and the inner cylinder is open at the bottom; this opening registers with a corresponding hole in the supporting manifold plate.

Right — a sectional view shows the direction of air flow through a typical arrangement of canisters. In this instance, each of three manifold plates supports 98 canisters; each canister decontaminates from 25 to 35 cfm of air. *All photos this page: courtesy of W. B. Connor Engineering Corp.*



cause activated carbon has no retentivity for pure water vapor. Upon saturation, usually after a year or more of service in the average air-conditioning system, the carbon can be reactivated to its original potency and, although this must be done under meticulous controlled conditions by the manufacturers, they usually facilitate this simply by exchange of the carbon containers thereby eliminating any interruption in service.

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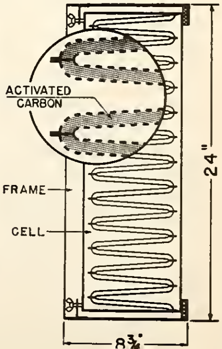
"The Toxicity of Ozone," by Dr. Clark E. Thorpe. *Industrial Medicine and Surgery*, Vol. 2, February 1950.

Below, far left — part of the 3400 canisters which bar fumes from the neighborhood surrounding the Washington D. C. Refuse Transfer Station.

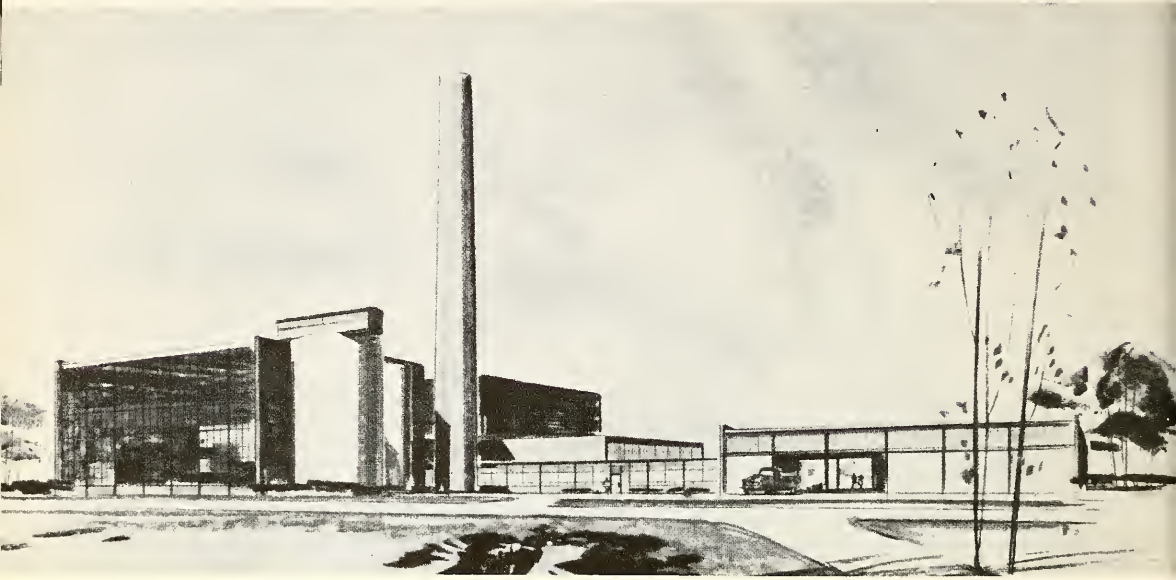
Below, left and right — photograph and drawing of cell-type activated carbon air purification equipment. Each cell purifies 1000 cfm of air at a resistance of about ¼" water gage.



Shopping Center Mechanical Design

BY VICTOR GRUEN

Provision of a central heating and air-conditioning plant will eliminate a 'multitude of scattered stacks and superstructures. The single plant can be unified in design with the total. Eastland Center (below) *by Victor Gruen.*



The heating, ventilating, and air conditioning of a preplanned, integrated shopping center is actually one of the most challenging aspects of the project. It is challenging because the possibilities for efficiency in installation and operation, which are inherent in a co-ordinated project, can not be realized without a complete change in the traditional owner-tenant relationship and division of responsibility.

Historically, the problem of heating and air conditioning store buildings has been managed in a haphazard way largely through expediency rather than upon a logical basis. The owner generally built his building with a particular tenant in mind. It was his responsibility to provide the heating plant—the tenant provided the maintenance and operation. If a tenant wanted air conditioning, the owner sometimes, and sometimes not, provided the duct work and the enclosures or supports for the air-conditioning equipment. The compressors, the air-handling equipment, fans, evaporative condensers, etc., were supplied by the tenant. Mechanically, this wasn't too bad a situation and it was possible to have a fairly efficient installation, if the tenant and the owner got together before the building was quite complete.

Architecturally, the results have not been so happy. The typical one-story strip development store carries a superstructure almost as impressive as the building itself; ducts run all over the roof and exhaust stacks, boiler flues, air intakes, evaporative condensers, or water towers are all arranged in a totally haphazard and disorganized fashion.

So long as each store in a group tended to be the property of a separate owner (the only relationship between stores was the party wall; the problems of expansion, contraction, alteration, and change were only considered as horrors to be faced later), there was no incentive or real reason to change this not too efficient pattern.

But the preplanned regional or district shopping center has introduced a brand-new set of factors. In the shopping center, the typical tenant building is not many little buildings all strung together; it is, rather, one large building, sometimes 400′ to 450′ long, uniformly designed, constructed for maximum efficiency, and capable of being divided in many ways to suit the leasing requirements of a multitude of occupancies. This element of being built all at once, and the ability to adjust to a variety of occupancy shapes and requirements, suggests the possibility that the heating and air conditioning might be conceived on the same basis—that there might be advantages in cost of installation, operation, and maintenance to be achieved by preplanning this part of the center.

Of course, it would be possible to wait until the building was rented and, as each tenant's requirements were established, to provide the heating plant and the duct work on the traditional basis — modifying the building; adding superstructures on the roof; erecting a scattered pattern of chimneys. But the only reason for doing this would be to maintain the tradition, to follow the pattern, without establishing whether the old pattern is right for the new concept of the shopping center.

Many aspects of the old system are not compatible with the aims of the planners and owners of the modern, integrated shopping center. Their desire is not only to provide convenient shopping, but shopping in the most pleasant and attractive atmosphere possible. The integrated, preplanned tenant building achieves order and uniformity plus a disciplined shape to house the individuality of each tenant as expressed in his storefronts and signs. As these buildings are set back from the street, surrounded by parking, and therefore visible at a distance, a disorganized array of roof equipment would not enhance the appearance, nor would smoke and fumes from rows of chimneys improve the shopping atmosphere.

As an alternate to this traditional, expedient approach to heating and ventilating, a preplanned building offers the opportunity to provide a central heating plant and a central air-conditioning plant of sufficient capacity to accommodate the needs of all tenants within the building. However, as the concept of the central plant departs completely from the historical owner-tenant relationship of cost and responsibility, it must be compared carefully with standard procedures and practices so that its advantages are clearly established.

This examination and comparison should be carried out from four points of view: initial cost, operating cost, flexibility, and the effect on the architectural design.

To determine the initial cost is relatively simple. Take a typical tenant building, fill it with a theoretical occupancy of stores and: (1) design a central system with the necessary distribution lines and ducts to serve the occupancy; (2) design an individual local system for each tenant in accordance with standard practice; (3) estimate the cost of each. Our experience has indicated that the central steam plant, serving a large group of tenants is, from a capital-cost point of view, more expensive than the sum of the individual plants in spite of the multiplicity of units, stacks, etc., involved in the local units. This appears to be due largely to the special character of central equipment as compared with the mass-produced individual units: and to the complex character of a central installation as compared with the simplicity of the installation of individual units.

An examination of operating costs, however, yields very different results. The maintenance, supervision, and fuel consumption of 10 to 12 individual units total approximately twice those of a central plant serving the same number of tenants. This engineering evaluation is borne out by the experiences of industrial plants, apartment house groups, etc., which have been converted from multiple to central installations.

To date, it has been impossible to confirm these operational estimates by figures from stores or chains that operate and maintain individual units, because the common practice of lumping electrical costs, service, and maintenance into the store operation, and of using either sales or management personnel for the operation and supervision of the boiler units.

As far as flexibility is concerned, there is no question that the central plant has advantages for the owner that the scattered individual tenant plants cannot hope to match. Changes in occupancy requirements, due to changes in merchandising activity or to the introduction of new units, can be met without structural change, and with only a minimum of mechanical alteration.

From an architectural point of view, the central system has many advantages: the elimination of a multitude of stacks, the localizing of the mechanical installation in one area, the opportunity of effective smoke control, and the simplification of framing by elimination of stacks. And for the tenants there is a distinct advantage in the actual saving of space — the area which would be occupied by boilers, fuel storage, and related equipment is released for merchandising or the processes necessary for merchandising.

For the landlord, the weighing of these four factors poses an interesting choice. The central plant costs more to install than the individual systems. The maintenance and operating expenses, which were formerly the burden of the tenant, must now be assumed by the management and distributed to the tenant on some equitable basis, such as the metering of the steam. The typical tenant has to be satisfied that the metered rate he is paying for the steam represents a lower heating cost than he would pay with an individual system. Yet there is difficulty in establishing what the tenant's cost would be with the individual plant because there are no clear records of this cost. The tenant must realize, however, that the diversion of man hours from the operation of the equipment to the actual management and selling operations of his store cannot be ignored, and that hidden maintenance and operating expenses are bound to be eliminated if shopping-center management assumes this responsibility.

The case for air conditioning is similar, but perhaps more complicated.

Air conditioning is not as simple a matter as the provision of steam. Tempered air can be produced in a number of ways. The central refrigeration and air-handling plant could easily supply the required volumes of tempered air to all the tenants in a building. But it is difficult, from a central plant, to adjust to individual requirements in any fashion other than by increasing or decreasing the volume of air in each space. If booster coils are provided, the system immediately becomes special. Tempered air can be provided by supplying chilled water from a central refrigeration plant to zoned, air-handling equipment units, each of which will serve a limited area. The chilled water can be metered on a thermal basis, and the air-handling equipment will be operated by the individual tenant as he requires. Or the central plant could produce only condenser water, which would be piped to zoned compressor locations. There are others, but these are the basic central-plant variations.

Each of these three must be completely laid out with their related duct work, electrical installation, etc., in order to establish a fair basis of comparison. And in making the examination and comparison, again the four factors involved are: initial cost, operating cost, flexibility, and the effect on architectural design.

Initial cost can be determined by laying out individual systems in accordance with standard practice for a theoretical pattern of individual tenants, and three central system variations designed to serve them all.

Our surveys have indicated that, from a total cost point of view and considering a group of approximately 12 stores, the initial cost is almost a toss-up with the central plant, providing tempered air adjusted on a volume basis, having a slight edge.

Our examination of the projected operating costs of the four possible situations shows the central refrigeration and air-handling plant providing total tempered air to be by far the most efficient. One of the principal reasons for low-operating cost of the central plant is that, while it is no longer unusual for a typical one-store installation to require and use more than 20 tons of refrigeration, local ordinances and controls now generally require the continuous presence of a first-class engineer for any installation of 20 tons or more. This means that six to eight engineers would be required continuously if the regulations are adhered to, whereas only one engineer with a helper would be necessary at the central plant.

Here, again, cost figures on individual installations are hard to check: condenser water is generally thrown away and lumped into the water bill; electrical consumption is buried in the total; most operating stores ignore the regulation requiring a registered engineer, and the same manager who operates the steam plant fiddles with the air-conditioning unit.

There is also the problem of distributing costs. Steam consumption can be easily metered—air flow, only with difficulty. And to distribute the cost simply on a square footage basis can result in inequalities because of differing hours of operation.

In considering flexibility, there is no question that the central plant has great advantages. Changes in merchandising techniques often introduce increased lighting loads in an individual store and require brand-new or additional cooling equipment; with a central plant system, however, the extra cooling can be supplied without additional equipment. Changes in store occupancy also can be accomplished with little or no structural or mechanical problems.

Architecturally, the central plant is a boon. The superstructures are gone from the top of the building. There are no exposed ducts crawling over the roof. Intake and exhaust stacks can be centrally located and specially treated. And, for the tenant, the space advantage gained from the elimination of the individual boiler plant is repeated by the elimination of the space required for the compressors, condensers, fans, etc., thus increasing his usable space and giving him a larger net area available for actual merchandising.

In addition to these purely theoretical considerations of cost and flexibility, there are limiting factors that may be dictated by facilities or conditions special to the location of the project. It is possible, even probable, that the sewer capacity available to a suburban shopping center will not be sufficient to permit total discharge of the condenser water into the system. Under these circumstances, evaporative condensers or cooling towers which permit recirculation may be mandatory. Or the water supply may be limited in the general area and, for conservation reasons, the use of condenser water restricted.

Where these conditions exist, our findings have indicated that the capital cost of a central plant is considerably less than the capital costs of a series of individual plants, each requiring its own water tower or evaporative condenser; further, the accumulated space lost where each tenant must satisfy these special requirements is excessive and imposes a burden on the tenant who must rent this space. (It also decreases the opportunities of profit to the owner, because this space is totally lost to sales, and so must affect the percentage rental payments.)

The decision on the method of handling air conditioning on an integrated basis is obviously a complicated one both for the owner and the tenant. If a central plant is introduced, a large item of capital cost, normally borne by the tenant, is completely eliminated and must be expressed in a change in the rental structure or charged to the tenant on some fair and equitable basis. Either of these alternates will be a major departure from the rental pattern experienced in other kinds of store locations and may be difficult to negotiate—particularly if the tenant may not be satisfied in his heart that the central plant means a savings.

Then, there is the question of the operating costs normally borne by the tenant which must, in a central plant, be carried by management and distributed to the tenant on the basis of his consumption. With a central cooling and air-handling plant, metering of the individual tenant's consumption by volume of air is, at present, unreliable. The distribution of costs on a square footage basis has many inequities because the volumes required by different types of occupancy will vary greatly.

The operation costs of a central, chilled-water plant can be fairly and equitably distributed where the zoned consumption of chilled water by the individual tenants can be metered on a thermal basis. But the operating and maintenance costs are slightly increased because of the necessity of tending the zoned air-handling equipment. It is also possible to meter the consumption of condenser water. But in this type of installation, the increased number of local compressor units vastly increases the operational and maintenance costs and, to a large extent, fails to realize the advantages in space saving, etc., offered by the central plant.

The Northland and Eastland Regional Shopping Centers in Detroit are being designed with central-heating and central-refrigeration plants. In making their decision, the owners agreed with the architects and engineers that the advantages in flexibility, efficiency of operation, improved appearance and shopping comfort, and the considerable space made available for merchandising, more than compensated for the increase in cost. These advantages are passed on to the tenant.

Newspaper Plant Air Conditioning and Ventilating

BY TYLER G. HICKS*

Newspaper plants require air conditioning as it is the only effective means of solving certain operating problems arising from the materials and processes of printing. Local ventilation with humidification of room air is another means of simplifying some production and comfort problems. But neither ventilation nor air conditioning alone is satisfactory—the modern newspaper plant combines the two to secure a carefully controlled atmosphere within the building.

paper characteristics

Newspapers are printed from rolls of paper by a process called *web-fed* or *web printing.* The paper is hygroscopic; its properties vary with the quantity of moisture it holds.

Paper rolls that lose moisture from their ends have "short" or "tight" edges. Cracks develop at paper edges and web breaks on the press may be frequent. This means press shutdowns may occur more often, cutting output. High-speed presses are expensive machines and any condition that reduces their production causes a direct loss on the initial investment for the press.

Static electricity and ink misting are two other newspaper problems caused by low-humidity, "dry" atmospheres in the pressroom. News inks are thin—they dry mostly by absorption. A change in pressroom temperature or the wrong temperature can affect ink viscosity, slowing production.

stereotype, engraving

Here we run into processes giving off large quantities of heat, others that require high relative humidities, room-air exhausting, special filtration to recover valuable materials, hood services of several types, and close control of atmospheric conditions. All are essential for economical, rapid, and safe production of modern newspapers.

Examples of stereotype-room problems include the large internal heat gains from lead melting and molding machines, mat formers, and scorchers. Heat, smoke, and foundry-like odors must be localized. Room temperature must be maintained higher than in the rest of the plant because personnel perspiration rate is high. Drafts are objectionable; they may endanger health. Besides these problems of heat and smoke, a high-humidity atmosphere is needed for conditioning stereotype-plate mats in storage.

The usual engraving department includes operations such as etching, drying, photography, and photo printing and developing. Controlled humidity, exhaust, and air filtration in the right combinations are usually satisfactory.

composing and pressrooms

Linotype operators must be able to concentrate on their operations without disturbances of drafts or uneven room temperatures. Fully-conditioned spaces carefully designed for the job are the only answer.

Recommended temperature and humidity conditions for pressrooms, stockrooms, and storerooms are listed (*Table I*). Five percent variation of relative humidity in the pressroom is allowable if production is to be satisfactory at all times. This and the 5-F allowable temperature variation result from paper characteristics.

The best humidity for roll storage is 50%; the best temperature is from 73 to 80 F. The job shop, a part of most modern newspaper plants, requires conditions fixed by the type of work done. (*Table I gives specifications for a typical plant.*)

editorial, circulation

In general these departments need only usual comfort conditions, summer and winter. Areas where work may resemble that in a typical office structure are editorial, circulation, recreation, cafeteria, library, and medical. These are common to many newspaper structures.

Areas needing other than straight air conditioning are kitchen, conference rooms, museum, first-aid treating, and cooking school. Where large changes in occupancy are expected, recreation rooms and cafeteria are made more comfortable by more than just air conditioning. Direct exhaust systems may supplement air conditioning and remove objectionable smoke and odors.

the sacramento bee

Application of the general principles that have been outlined will vary from one newspaper plant to another, depending on location, architectural treatment, press types, job-shop size, and many other factors. *The Sacramento Bee* is an example of advanced design because it combines modern interior and exterior treatment with year-round air conditioning.

All departments in both the administration and mechanical buildings are conditioned throughout, under complete automatic control. Hoods and mechanical exhausts are used in all places where newspaper equipment generates heat or fumes. Locker rooms and service areas have similar exhausts.

Table I: Temperatures and Humidities for Printing Plants*

Process	Temp F	R.H. %
Pressroom:		
Newspaper and other web printing	75-80	50-55
Multicolor offset lithography	75-80	46-48
Other sheet-fed printing	75-80	45-50
Stockroom:		
Roll storage	73-80	50
Multicolor offset lithography	73-80	5-8% above pressroom[a]
Other paper storage	70-80	[b]
Binding, cutting, drying, folding, and gluing	70-80	45-50

[a] 5 to 8% above pressroom
[b] same as pressroom
Notes: Air from pressroom and storage rooms should not be recirculated through office areas. Provide hoods for gas dryers (solvent recovery recommended for all except job shops). Exhaust system with dust collectors incorporated is required for type- and plate-cleaning areas. Check use of gasoline and other solvents.
* Abstracted from A.S.H.V.E. Guide, 1952, p. 942

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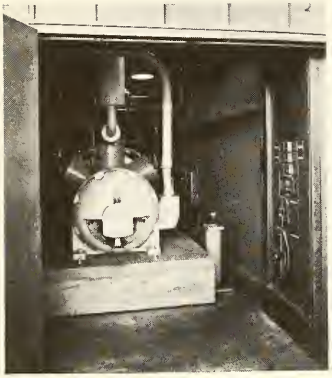
* *Associate Editor,* Power

Figure 1—one of two refrigeration compressors used for building cooling at the Bee.



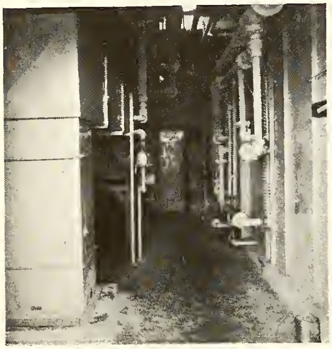
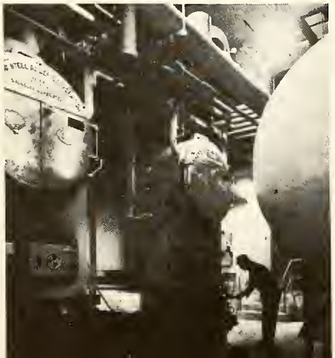


Figure 2—fan room in mechanical building contains newsroom air-conditioning system (right) *and composing room system* (left).

Figure 3—two low-pressure heating boilers supply steam and hot water; burn natural gas or oil.



The extent of the air-conditioning installation will be realized when one sees that the entire basement (except for photoengraving department and job shop at north end, reel room for press, ink room, boiler room, and electric service room) is available for newsprint.

system design details

Sun load can have a major effect on refrigerating-system loads during the summer. To reduce sun load and system operating cost, all *Bee* windows exposed to the sun have adjustable louvers. These allow blocking of the rays as the sun travels from east to west, preventing large fluctuations in heat load. Roof decks are well insulated for the same reason.

All outdoor air introduced into the building is filtered. Every cubic foot of air circulated inside the building is filtered about eight times per hour for dust and pollen removal. Most air is further cleansed and conditioned by passage through water sprays.

Room air is supplied through slotted openings in the top of continuous cabinets located under the windows. This blankets exterior walls with cool air in summer, warm air in winter.

The air-conditioning systems using refrigeration require no reheating in summer. This reduces operating costs to the lowest possible figure for a fully air-conditioned building. Instead of a reheater, hot and cold plenums are fitted at supply-fan discharge. The cold plenum is kept at a low enough temperature to satisfy any one of the various zone-supply ducts. The hot plenum handles recirculated room air in summer. In winter the air in the plenum is heated only enough to offset building heat losses. Each zone duct connects to both hot and cold plenums. A pair of dampers automatically admits the correct percentage of hot and cold air to the zone duct, according to the demand of the zone thermostat in the conditioned space.

The system of this design is most flexible because as many different temperature conditions can be obtained as there are zones. The three double-duct systems installed in the building replace 33 individual systems which would otherwise be needed. The results are equally satisfactory.

Relative humidity throughout the building is automatically reduced in summer and increased in winter to provide maximum human comfort. Winter humidification is automatically maintained at comfort condition by means of recirculated water sprayed over the cooling-coil surface over which air is drawn. Humidistats control all phases of this process.

At least two fans are used in each air-conditioning system. One is the usual supply-air fan, the other a recirculated-air fan. The latter can automatically vent large volumes of air when the systems run with 100% outdoor air. They are automatically controlled so that when the outdoor-air temperature is suitable for cooling, the refrigerating plant is shut down and a mixture of outdoor and room air is used for cooling. Therefore, if there should be a breakdown in the refrigerating units, it is possible to run all air systems on natural ventilation and mechanically exhaust all air introduced into the building. This is extremely important, should an interruption in refrigeration service occur in summer. Also, it is common practice to seal and lock the windows in fully air-conditioned buildings to reduce dust infiltration. Having air available during refrigeration failure eliminates the need for opening building windows.

cooling, refrigeration

During plant design, extensive studies were made in an attempt to apply the principle of the heat pump to the building heating and cooling systems. But the heat pump did not prove economical in any respect for a building of the *Bee's* character. Its application was discarded after a careful comparison of costs and operating results with well water and refrigeration systems (*Figure 1*).

Water from two deep wells is used for cooling in several of the air-conditioning systems handling large volumes of outdoor air. The water is then reused in the condensers serving the refrigeration systems. Heat abstracted from the air and refrigerant is added to the well water during each step and the warm water is wasted.

Systems utilizing well water for summer cooling are arranged so that well water can preheat outdoor air introduced into the building in winter. A substantial heating-fuel economy is realized for systems handling large volumes of outdoor air, when compared with the cost of gas or oil fuel.

Well water is also used for cooling and setting molten-lead newspaper plates in the stereotype department. The system includes a large well-water storage tank with circulating pumps, piping, and automatic controls which maintain the cooling water at the desired temperature for the best results in setting the lead plates.

building heating

The heating plant consists of two low-pressure steam boilers (*Figure 3*) fired by natural gas with standby facilities so that heavy oil may be burned at a few moments notice whenever gas service is curtailed by the local utility company in severe weather. Domestic water is pumped through heating coils immersed in the boiler water, then stored in tank reservoirs, ready for use. The system is automatically controlled.

pressroom

This is cooled in summer and heated or cooled in winter by a central-station air-conditioning system handling 100% outdoor air and using well water for cooling. All outdoor air is used so that the room is purged of ink and oil mist and paper lint from presses. Recirculation of air from this room would introduce costly and troublesome maintenance problems from ink, oil, and paper.

Outlets discharge reel-room supply air at the floor. Low-velocity pan outlets (*Figure 4*) supply air below press catwalks in the pressroom. Low-velocity low-level air distribution secures the maximum cooling effect from the supply air. Since heat generated by a press comes from friction throughout the length and height of the press structure, the heat rises unhampered to the room ceiling. Here it is exhausted directly by roof ventilators arranged for easy cleaning. Direct removal at a high point in the room prevents most of the heat from affecting room temperature at operating-floor level.

Conventional mixing-type air outlets were not used because they would interfere with the warm air current over the press. About one-third of the additional cooling effect obtained by pan outlets would be nullified by conventional outlets. Temperature reductions of 5 to 7 F have been observed in pressrooms cooled by pan outlets and ceiling exhaust. Also, it is possible to make a substantial reduction in system air capacity below usual designs. This cuts operating costs.

The supply-air fan has a two-speed motor to allow a 50% reduction in air capacity for winter operation. This also reduces air movement to a minimum during the winter, improving personnel comfort.

Summer cooling is done by two banks of well-water coils. One bank is in a sprayed-coil section for winter humidification. The choice of well water was based on the fact that it gives a good economic balance between costs and room temperature conditions where space needs larger volumes of outdoor air to replace air exhausted and where there are high internal heat gains. Well water is reused in the refrigeration system before being wasted.

stereotype room

The supply-air system is the same as for the pressroom. Specially constructed hoods with direct mechanical exhaust relieve heat from lead melting and molding machines, mat formers, and scorchers. As a result, the total exhaust quantity is high and exceeds the amount of air supplied to the room. This produces a negative air pressure in the room and heat, smoke, and foundry odors are localized.

Stereotype mats are stored in a separate enclosure automatically maintained at high relative humidity for mat conditioning.

Hoods for stereotype pots are No. 10 gage steel plate to withstand rugged use and to prevent buckling from heat given off by lead. The hood encloses the entire pot and has self-closing doors to prevent spilling or splashing of lead during loading. Dross is skimmed off the top of the liquid lead through other doors. The operator adjusts the quantity of exhaust air to suit working conditions.

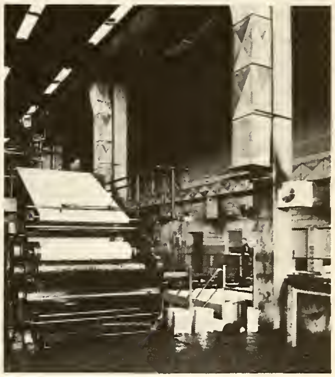
Personnel perspiration is unavoidable in this room because equipment has high radiant-heat loss. Room temperature 5 to 10 F higher than usual is needed for the best comfort conditions. Careful placement and design of air supply ducts will eliminate drafts.

composing room

A double-duct system provides full air conditioning. Interior space as well as each wall exposure is separately zoned. Heat gains from closely spaced linotype machines and high-intensity lights are large. For best results heat-load computations should be made for each bay and the required air volume for the bay established. Then uniform temperature throughout the area will be obtained. Supply-air outlets chosen (*Figure 5*) must be suitable for good air mixing and temperature equalization without drafts.

About 50% of the total air supplied this room is outdoor air. This is needed to partly offset direct exhaust from some equipment and for diluting oil mist, lead fumes, and smoke haze coming from linotype machines. Good zone control is needed because the heat gain from linotype machines varies from 25% to 100% of full rated motor and heating-element capacity, depending on speed. No fixed humidity is

Figure 4—low-velocity pan outlets in pressroom are at bottom of drops from large ducts.



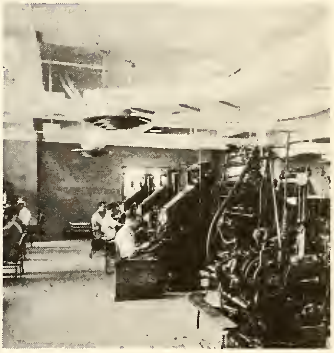


Figure 5—overhead outlets supply air to composing room containing linotype machines.

Figure 6—advertising makeup also requires controlled air conditions for comfort and efficiency.

needed for any operations in this department. Automatic controls maintain standard comfort conditions in winter.

engraving department

A central-station air-conditioning system handles 100% outdoor air for the makeup of direct exhaust. Full air conditioning was selected because the department has no exterior exposure. If this were not so, something less than full air conditioning would probably be satisfactory. Usually, people confined indoors need lower temperature conditions for the same sensation of comfort felt by people working near windows.

A single duct supplies the entire area, the temperature for different rooms being regulated by gradual-acting dampers in branch ducts. Dampers are automatically controlled by room thermostats.

Etching-department operations require several types of direct exhaust and hoods. Zinc and copper etching machines have enclosed stoneware tubs containing acid and a wooden circulating fan, with air slots and an exhaust outlet. Stainless-steel ductwork under suction is connected to the exhaust outlet and has the means to vary the quantity of direct exhaust from the machine. Ductwork must be soldered and the condensation collected and drained.

Table-high enclosures for manual dusting of engravings are called powder boxes. Velocity across the enclosure opening must be high enough to contain powder within the enclosure but not so high that the powder is drawn into ductwork. Plenum space having a fine cotton-bag filter is built at the top of the powder box and connected to the direct exhaust system. The bag has a shaking device to keep it in good condition.

Conventional hoods connected to direct exhaust are used for gas stoves and dryers. Acid is stored on a prepared section of the floor against a wall. A stainless-steel duct on the wall behind the acid carboys exhausts air through high-velocity slotted openings in the duct, quickly removing fumes.

Photographic dark rooms have a direct exhaust above sinks and a conditioned air supply less than exhaust volume. This maintains a slight negative pressure in the room. Camera rooms using cameras and arc lights have high internal heat gains while the arcs are in use. A direct exhaust register on the camera center line and midway in the arc's travel removes heat from the room.

Conditions in printing rooms are somewhat similar to those in camera rooms. Room temperature and humidity must be held as nearly constant as possible when sensitized paper is being handled. This prevents stretching or shrinkage during printing or while the paper is in storage.

other rooms

A central-station air-conditioning system using well water serves the mail room. Ceiling outlets of the air-mixing type evenly located in the room distribute air uniformly throughout the room. No special problems are encountered.

Grid-type secondary resistors are used for press speed control. Located in a separate room, the resistors are in fan-cooled cubicles hooded and vented directly outdoors. Replacement air enters through louvers in the exterior wall. Louvers have air filters to keep electrical equipment free of dust. Outdoor air is not heated in winter because equipment in the room does not need constant attendance.

statistics

The main air supply and exhaust quantities are summarized (*Table II*). Also listed are important items of equipment used for heating, refrigeration, air washing, and cooling-water supply.

The mechanical design of a building of the *Bee's* type requires far more study than the average office building or similar structure. Heat loads for a variety of processes under different operating conditions must be determined. Careful air supply and exhaust balances must be worked out for each room to insure the best comfort conditions. Not only is engineering skill needed for the system design but good judgment must be used in evaluating heat-load data. Long experience coupled with engineering skill are the best tools for approaching the design of plants such as the *Bee*.

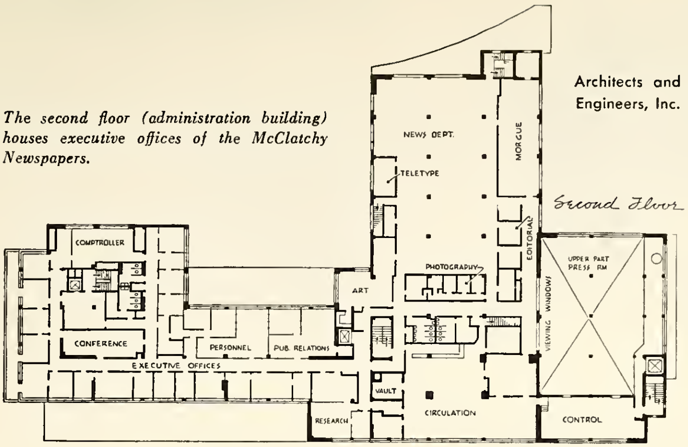
Table II: Sacramento Bee Air-Conditioning System Design Details

Area	Total air supplied	Direct mechanical exhaust	Outdoor air supplied
Press	30,600	32,000	30,600
Stereotype	9,000	9,000	9,000
Composing	18,000	4,500	4,500 min
Engraving	6,000	6,300	6,000
Mail	13,000	—	2,600 min
Press control	14,000	14,000	14,000
Kitchen	—	2,500	—
Locker rooms, etc.	—	15,400	—
Newsroom, Circulation	15,000	—	2,500 min
General Offices	50,000	—	10,000 min
Totals	155,600	83,700	79,200

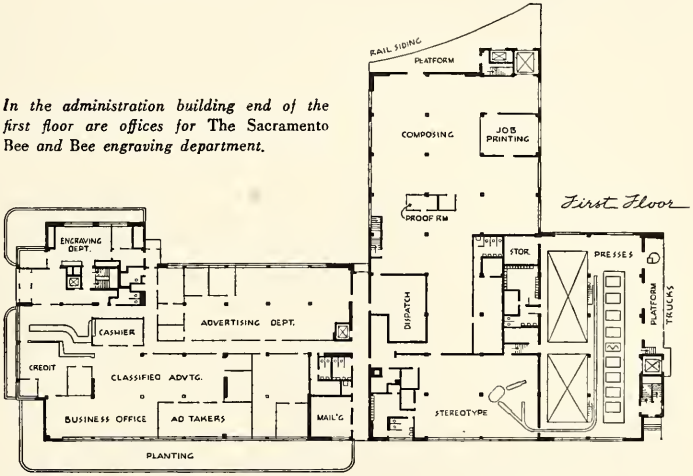
Heating equipment:
  Boilers (2) 8,500 sq ft edr, 15 psi, natural-gas or oil-fired connected to two-pipe system
  Condensate pumps, duplex, operating on gravity return
  Direct radiation, at all entrance doors from street, shipping doors, and stair towers
Refrigerating equipment:
  Compressors (2) direct-expansion with step-type unloading controls, total capacity 300 tons
  Air washers, sprayed-cooling sections for seven systems; total capacity 135,600 cfm
Well pumps:
  Deep-well turbine-type (2) 200 gpm and 500 gpm, to furnish water for air cooling, refrigeration condensers, and stereotype-plate cooling

Architects and engineers: Lockwood Greene Engineers, Inc. Designer: Dunbar Beck.

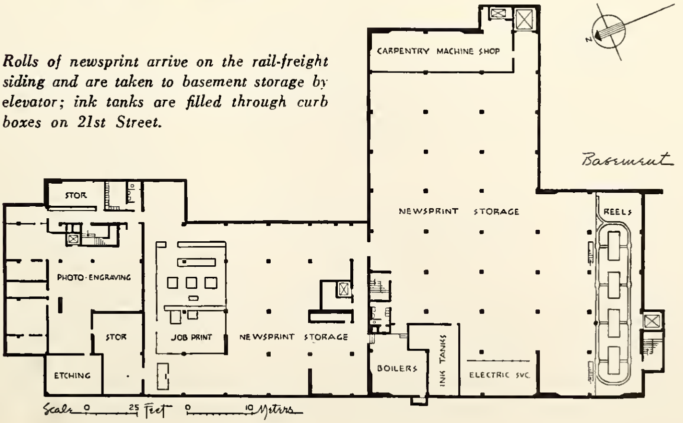
The second floor (administration building) houses executive offices of the McClatchy Newspapers.



In the administration building end of the first floor are offices for The Sacramento Bee *and* Bee *engraving department.*



Rolls of newsprint arrive on the rail-freight siding and are taken to basement storage by elevator; ink tanks are filled through curb boxes on 21st Street.



SUN ANGLE DATA

To know how the sun's rays will strike a building and how far they will penetrate through openings, to know if certain areas should be shaded and others irradiated, to know how to use the sun for supplementary heating or to study the effect of solar energy on air-conditioning capacity and operation, one must have the following data: (1) the angle of the sun above the horizon; (2) the bearing of the sun, or its direction with respect to the points of the compass; (3) the angle of incidence of the sun's rays with respect to the surface being considered. To obtain these solar angular values quickly and easily, an instrument was needed which would give all of the necessary values for all possible conditions of time and orientation in terms that could be applied directly to the drafting board. To supply these needs, the Libbey-Owens-Ford Glass Company developed such a device, known as the Sun Angle Calculator, which greatly simplifies the analysis of sun control problems. The elements of the calculator consist of an index map, sun charts, overlay, and cursor. There are sun charts for each four degrees of latitude from 24° to 52° north latitude (the entire United States lies within these parallels). These charts, made of white plastic, are printed on both sides in black. One transparent overlay, printed in red, is applied to all of the charts; it is pivoted in the center and rotates when placed in position. A clear plastic cursor pivots about the center point of the overlay and with it one reads the true altitude of the sun and also the bearing of the sun from true south and from normal to the window. The cursor intersects graduated scales along the perimeter of the sun charts and overlay. Armed with this calculator and an appreciation of the considerations brought out in the following article by Groff Conklin, the designer has the basic tools required for the proper control of the sun.

Sun Control Methods

BY GROFF CONKLIN

This open type structural overhang, on a British school, illustrates both the merits and faults of such a sun control method. If the louvers are adjustable, the sun's *heat* will be successfully barred from the room during the hottest part of the day, when the sun is high. But the overhang is valueless in controlling glare when the sun's *light* is most uncomfortable, during the early morning and late afternoon hours. *Arcon, Chartered Architects*
Photo: Sidney W. Newbery

There is no doubt that we are entering an era in which the use of large expanses of glass in all types of buildings is going to become increasingly accepted practice. The advantages of window walls from the various points of daylighting, winter heating economy, and the sense of freedom and good health which the openness of a large window gives to people, are enormous. In the words of Architect Charles Goodman, of Washington, D.C., the large glass area provides the individual with a kind of "multiple spatial magnetism: open, airy, visually unrestricted space that allows the human eye the freedom and variety of focus necessary to restfulness and psychological relaxation at all ages of the human mechanism and in all its stages of health."

Along with the glass wall, so-called, trails the problem of controlling the uninhibited sun which immediately floods the rooms in buildings so provided. It is a truism that completely satisfactory control of solar radiation and sunlight inside a structure with large glass areas is impossible, since the solution requires a compromise between diametrically opposite situations. One enlarges glass areas to increase daylighting efficiency and home livability, and then shades or drapes the openings to reduce glare and achieve privacy. One orients buildings for maximum sunlight reception in winter, and then builds in heat-absorbing glass to reduce excess summer radiation—which, in turn, considerably reduces solar heating efficiencies in the winter! One builds overhangs above and at the sides of windows, carefully designed to admit maximum sun in the winter and minimum light in the summer and finds that unfortunately the sun's rays still creep in no matter how effective the overhang, and window coverings are still essential. Though the sun is our friend, without whom we could not live, it is also something of a persistent nuisance from whom we need at least a minimum amount of protection for our own comfort.

problems of sun control

That "sun control" is not a simple matter susceptible of easy solutions is made obvious when one summarizes the more important problems which are encompassed by the phrase. Here is a list of them:

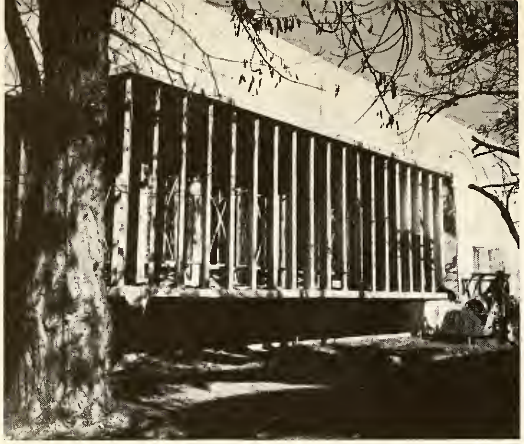
1. Minimization of glare, summer as well as winter.
2. Minimization of glare and reduction of eyestrain at all hours of the day in an exposed room.
3. Minimization of solar heat entering rooms in summer.
4. Maximization of solar heat entering rooms in winter.
5. Adjustment of solar heat to maximum operating efficiency of heating and cooling systems.
6. Control of condensation at windows in wintertime.
7. Insect, dirt, and dust control at openings.
8. Protection against rain, snow, and wind at openings.
9. Provision of adequate ventilation at all times.
10. Arrangements for privacy when needed.
11. Maintenance costs versus original costs of sun control devices.
12. Provision of adequate exterior vision; restful and non-distracting outside environments in non-residential buildings.
13. Exterior appearance: the architectural or esthetic factor.

Every building will present a complex of many or all of these problems, and no solutions will be automatic. They will take a good deal of careful thought, particularly in view of the highly technical physics of solar radiation, optics of various glasses, and psychology of daylighting. Wise indeed was the young architect who recently said: "Whenever I have a job which requires a large-scale analysis of the effect of solar radiation and glare on livability or working efficiency I call on the technical staffs of the companies manufacturing sun control devices, or on independent consulting engineers in the fields of daylighting, heating and air conditioning, for expert advice. I early realized that the field is much too specialized for the average architect, except in the case of very simple problems. I have neither the time nor the training to be an expert in daylighting, so I use the technicians as a sort of extension of my own office whenever a problem in sun control comes up. Thank God for them—if they were not in business, I probably wouldn't be, either."

methods and devices for sun control

This special statement should not be taken to mean that every small job calls for the special attention of the experts. It does, however, underline the complexities of the question; and the following list of techniques for controlling solar heat and glare makes even more clear the fact that a solution to the problem of sun control is not one to be worked out in an afternoon.

The most important techniques for sun control are as follows:



These deep vertical louvers, slanted to intercept the sun during the hottest season of the year, not only control both heat and glare effectively, but also give the building distinction. They would be most effective, of course, were the louvers either manually or automatically adjustable to the varying angles of the sun's radiation from season to season.
Clark and Buettler, Architects

Natural devices: building orientation, trees and shrubbery, shade of other buildings and projecting wings, geographical elements such as hills.

Around windows, outside: balconies, arcades, canopies and overhangs, arbors, eggcrate overhangs, solid horizontal and vertical fins, deep reveals, awnings of cloth or metal.

Over windows, outside: shutters, fixed or movable louvers, fixed exterior Venetian blinds, heat-absorbent storm windows or glass jalousies in addition to the regular window, Venetian screening, paint or whitewash (used mainly in greenhouses and, rarely, in factories where glare has proved an annoying problem).

The window itself: heat-absorbing glass, double glazing, glass jalousies and awnings, glass block, frosted glasses, elimination of windows entirely.

Over windows, inside: single or double cloth roller shades, slatted bamboo shades, Venetian blinds either horizontal or vertical, draperies, glass curtains, venetian screens inside casement windows.

Interiors: scientifically planned interior decoration and furnishing to reduce glare.

the windowless building

Of the above solutions or devices, only one is absolutely perfect; that is the building without any windows at all. Perhaps the time will come when—as the result of factors very different from those an architect considers in designing a building—the windowless structure will be home for all of us—probably under ground, at that. But until that time, buildings without windows are for most uses bad in every way. They tend to give their occupants a permanent feeling of claustrophobia which, in commercial and industrial structures, reduces efficiency and probably increases labor turnover.

Of course, certain types of buildings, such as storage warehouses, are naturally windowless, and certain other types, such as modern department stores, can be windowless without serious side effects. Furthermore, some manufacturing processes, particularly chemical, require minutely controlled temperatures and lighting intensities which can be provided only in windowless areas. But in the case of these manufacturing plants, the processes requiring such careful controls usually can be segregated in the interior of the building, while the offices, hallways, recreation and dining rooms and even work areas not requiring such controls can be daylighted. In general, the windowless building in which human beings are supposed to work is a stupid and inhuman solution to the problem of sun control.

orientation

Buildings without windows cannot even be considered under usual circumstances. Consequently the sun itself must be faced and controlled by the architect from the very start of the design of the building. And this can best be done by beginning with intelligent orientation of the structure on its site, together with placement of wall openings in logical relationship to this orientation.

The purpose of orientation is to control by geographic means the entry of the sun into necessary wall openings. Practical orientation depends not only on the fixed angles of solar radiation at various hours of the day and various seasons of the year, but also on prevailing winds, site shape and contour, zoning and building code restrictions, relative humidities at various times of the year, relation to other buildings and to natural cover such as trees and shrubberies, and local microclimatic conditions such as air currents due to adjacent hills or slopes, humidities arising from nearby bodies of water, and so on. The average number of bright days compared with cloudy or rainy days will also be a factor in specific areas, as will the question whether summer heat or winter cold will be the most serious problem. Finally, orientation and its relation to architectural treatment, engineering costs and use of extensive substructures will be affected by the type of building use, the budgetary limitations, the personal tastes or advertising requirements of the client, and the special predilections of the architect himself.

Much help on the macroclimatic aspects of building orientation can be obtained from the United States Department of Agriculture's Yearbook for 1941, which is called *Climate And Man.* Maps showing the distribution of clear and cloudy or rainy days for various areas in the nation are included in this book, as well as much valuable data on temperature ranges winter and summer, frost dates, rainfall and snowfall averages, number of foggy days, and lengthy reports on general weather conditions for each state. For more specific data on the weather in an indi-

Left: a canvas awning supplements and becomes part of the roof overhang on this drug store in northern Ohio. *Ernst Payer, Architect; Photo by Rodney McCay Morgan.* Above: display windows in the peristyle of this clothing store are sheltered from the sun at all times by these adjustable exterior venetians. *Gruen & Krummeck, Architects Photo: Roger Sturtevant*

vidual community, the assistance of local governmental agencies concerned with the problem should be obtained. Quite probably a good deal of original research by the architect himself will have to be undertaken if a thorough job is to be done.

In view of the decisive economic and psychological gains derived from scientific building orientation, it seems obvious that much care should be taken to assure the client the best possible location of his structure and the most effective placement of wall openings in that structure. More detailed discussions of the actual problems of building orientation can be found in "Regional Climate Analyses," a series of articles inaugurated by the *Bulletin of The American Institute of Architects*, September 1949, in collaboration with *House Beautiful.*

the best sun control is from the outside

Once a building is effectively located on its site, the problem then arises as to what device or combination of devices to control solar radiation and glare should be used at its windows and window walls. The selection of methods will depend on a wide variety of factors, of course; but as far as the relative merits of any particular device goes, technically speaking, it must be realized that none is perfect. All have their defects which must be compensated for. It is the architect's job to choose those devices which will do the job he wants done best and with the least trouble and expense.

One basic principle can, however, be applied to all solar control in buildings in any part of the country: and that is, if a solar radiation control device is to control heat effectively, it must be located outside rather than inside the window. Inside devices that are useful for eliminating glare have little or no effect on heat. Indeed, many of them have a tendency to store and reradiate the sun's heat which comes through the window glass. Drapes and roller shades may or may not reduce heat, depending on the materials from which they are made, but only by eliminating or at least drastically reducing light entering the room, thus defeating half the purpose of a well-windowed building. Shades tend to store heat and reradiate it into the rooms, no matter how they are regulated. Careful interior decoration schemes, based on colors and surfaces designed to diffuse rather than reflect light, will materially reduce glare but will have little or no effect on radiant heat from the sun.

Consequently the most effective sun control devices are those which are placed on the outside of a building, or—in special cases—as parts of the outer surface of the window itself. Most important of these exterior sun control devices are structural overhangs of various sorts, heat-absorbing glass, jalousies, awnings, exterior venetian blinds, double windows, and natural planting of trees or, perhaps, vines growing on arbors.

structural sunshades

The use of structural projections over or at the sides of windows and glass walls to serve as sun control devices is most common in buildings erected in very warm climates, as in Brazil and Tel Aviv, and more recently in the so-called "solar houses" which have large walls of glass needing protection from the sun's rays, and which seem to have originated far north in Wisconsin or Minnesota. Actually, overhangs are no more and no less efficient in the north than they are in the south. They may consist of cantilevered overhangs or balconies, open eggcrate sun deflectors, deep reveals, and vertical or horizontal fins or visors, slatted or solid. To the architect the use of these devices presents a complex problem, the answer to which must be compounded out of economics, esthetics, and technology. Structural sun control devices in general add considerably to the cost of a building. On the other hand they are architecturally attractive if well used and may be included if the client can afford them and likes their appearance.

Technically, however, their value is dubious. No structural sunshade is really efficient. It cannot, by its very nature, function perfectly for more than two or three days a year, since it is designed in accordance with some optimum angle of solar radiation. When the solar angle is nearer horizontal than that, too much sun enters; when nearer vertical, the room may become gloomy. Even semi-perfect operation can be expected for only three to four weeks a year, around the time when the sun's relation to the overhang is at its most effective.

In other words, no matter how carefully the structural sun control device is designed, other devices will be necessary for a large part of every working day on the openings in walls most exposed to the sun's rays. The experience of the Longfellow Building in Washington is proof of that. Most of the overhang-protected windows in that building have in recent years also been provided with Venetian blinds—a significant comment on the general usefulness of the cantilevered sunshade.

Perhaps the only place in the building field where the structural overhang has a high esthetic value which is commensurate with its cost is in the private residence. Here the overhang can be achieved merely by extending the rafters as far out over the window area as desirable, often by means of secondary members firmly attached to the rafter itself. Though this may bring the level of daylight below the minimum required for reading fine print, it still means that the rooms so protected will be relatively cool and shaded in the summer when the sun rides high, and flooded with sunlight in the winter when it is lower in the heavens. As experience has shown, drapes, glass curtains, interior venetians or bamboo roll screens are usually installed in this type of house not entirely for sun control but also for the privacy they afford.

Similar overhangs often prove efficient and relatively inexpensive on single-story or, at most, two-story non-residential buildings, such as schools, hospitals, and commercial structures such as shopping centers.

A frequently effective type of overhang for sun protection in small buildings is the horizontal eggcrate canopy or terrace arbor which can be covered with a roll-up canvas or over which greenery can be grown for summer sun protection. Obviously this sort of overhang is ill-suited to large multi-storied buildings, but its relative inexpensiveness makes it particularly suitable for the small-budget, low structure, no matter what its use.

Most structural overhangs can only be effectively worked into the design of new buildings; they frequently stick out like sore thumbs when added to old ones. All other methods of sun control discussed below, however, can be applied either to new or old structures, although even with many of them a better effect can be achieved if the devices are planned along with the building.

awnings

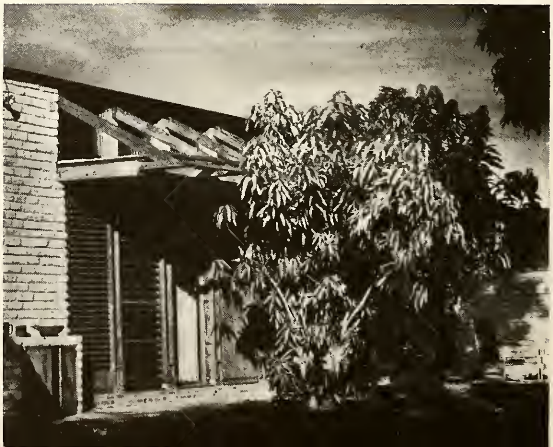
One of the oldest sun control devices is the canvas awning. There are still hundreds of thousands of homes and office buildings in which individual windows are shaded from the sun by adjustable awnings, usually made of a brightly striped cloth which strikes a jarring note against the quieter background of the building itself. This type of device has decreased in popularity of recent years, not only because of the fact that its original installation becomes rather costly when it is used over the wide "picture windows" and glass walls of modern structures, but also because of the comparatively short life and high maintenance and repair costs of canvas exposed to the weather. Furthermore, if cloth awnings are dismantled at the end of each warm season, the cost of doing so in commercial buildings becomes a sizable factor. There are, of course, special situations in which canvas awnings are still acceptable, particularly in view of their relatively low first cost.

Replacing the cloth awning in many parts of the country are wood or metal fixed awnings with movable slats, or metal awnings with nonadjustable surface units which can be retracted or rolled up against the wall. The first type provides effective control of the sun since the slats can be tilted to any desired angle, admitting as much light as wanted while eliminating glare and furnishing ample ventilation. The roll-up metal awning is obviously more flexible even though minute control of the sun's rays is not as easily accomplished as with the fixed, movable-slat type. A nonretractable awning will always be a difficult element to cope with, architecturally; the retractable type does not present this problem.

Metal or wood slat awnings obviously have a much longer life than those made of canvas, which more than compensates for their original higher cost. Furthermore, they tend to reflect the sun's heat outside the room from the upper surface and to reradiate heat penetrating the material from the bottom surface, thus keeping the rooms much cooler. Canvas awnings, though fairly effective heat barriers, keep air within the room from circulating and consequently help to build up a real heat load on hot summer days.

exterior venetian blinds

Fixed exterior venetians, usually of metal but sometimes of wood, are permanently fastened over the outside surface of the window. They are quite common in the south and southwest. These devices combine good ventilation control with adequate solar heat and glare management, store protection, and burglar insurance. On the other hand, they interfere with daylighting and the view from the window, since the blind itself is fixed and cannot be pulled to the top as can interior venetians. Consequently the exterior venetian is somewhat awkward to deal with ar-



Here the old-fashioned window shutter is put to a new and attractive use, both as a sun control device and as an architectural accent. Combined with the uniquely designed roof overhang, these wood jalousies with adjustable louvers provide an inexpensive, handsome solution to the problem of controlling solar glare and heat at all times of the day.

Igor B. Polevitsky, Architect
Photo: Rada Photography

chitecturally, in terms of exterior appearance, and has its disadvantages from the interior as well, since even when the slats are absolutely horizontal they are definitely visible and turn the window area into a series of lateral stripes which are damaging to a handsome view. For this reason it seems likely that this type of venetian blind, which has only recently been introduced north of the Mason-Dixon line, will be more or less limited in application in regions of more moderate temperatures to industrial and commercial buildings where exterior appearance is not of such great importance and interior views are not as essential as comfortable and airy working conditions. One important aspect of the exterior venetian is that it much more effectively bars solar radiation on hot days than the interior type because of the fact that the heat reradiated from the bottom surfaces of the slats escapes into the outer air rather than into the room. In this they have much the same value as the awning, though, since the whole installation is right next to the window rather than away from it as is the awning, some of the reradiated heat may get into the room by mere propinquity.

This problem was solved by an excellent type of exterior venetian blind which was available before the war but which now seems to be off the market. This venetian, which was held away from the window by a metal frame so that at the bottom there was up to about three feet between it and the wall surface, could be pulled up to the top of the window when it was not wanted. When in use its slats could be controlled from inside the house to direct the solar radiation away from the room. Thus every problem of solar heat and glare control could be handled by simple manipulation of the blind. It would seem logical that a retractable outside venetian blind of the awning type with adjustable slats would find a large market if it were available today.

venetian screens

One of the newer developments in sun control from the outside of the house is the venetian screen or "shading screen" as it sometimes is called. This is a screen-like product made of very narrow strips (less than 1/16″) of extremely thin bronze or aluminum, spaced 16 to 20 strips per inch and held rigid by vertical reinforcement spaced ½″ to 1″ apart. The horizontal strips are permanently slanted outwards and downwards at an angle approximately 20° from the horizontal, so that they block a large part of the sun's direct radiation and provide a diffusion of light that prevents glare as well. Though it is several times more costly than regular screening, Venetian screens, by killing two birds with one stone (insect control and sun control) often turn out to be a real economy. It is true that they reduce visibility inside the room to some extent—more than ordinary screens—so that the view through them seems somewhat fuzzy. This of course is no defect in nonresidential installations, and even in homes can be borne with, in view of the high degree of control of the sun's heat and glare which they provide.

trees

From many points of view the best method of controlling the sun, when it can be made use of, is practically free. Never was there a better sun-control than a tree, which needs no painting, washing, adjustment, seasonal removal or replacement, or repair. Plant it wisely, tend its growth when necessary and you have an ideal natural sunshade for low buildings. Many architects recently have been proving to their own satisfaction and that of their clients that a broad-leafed, deciduous tree provides better sun control than any type of manufactured device, particularly the structural sunshade. Such a tree affords ample shade in the summer when it is most needed, permits practically all of the winter sunlight and sun heat to enter the building through the leafless branches, and—perhaps as important as anything else—gives the building a human, natural, livable environment far pleasanter and more restful than the mechanical, chilly efficiencies of masonry, metal or painted wood.

Particularly for institutional and residential buildings sufficiently low to take advantage of natural shade, sun control should be provided by trees whenever possible. Indeed, many commercial and industrial buildings now in existence gain a high degree of sun control around the lower floors from the oaks, elms, and maples which a previous generation planted. The major difficulty with the tree as an immediate means of sun control in new buildings is that small ones do not actually control, and large ones are likely to be expensive. Even so, the cost of trees large enough to shade a low building will in all likelihood be less than the cost of efficient manufactured sun control devices.

Visible proof that nature can create the most effective of all sun control devices in the form of foliage. It is true that the architects have provided a wide roof overhang, but note that the tree completes the solar control which the overhang achieves for only about two-thirds of the window's height.

Wurster, Bernardi & Emmons, Architects
Thomas D. Church, Landscape Architect
Photo: Roger Sturtevant

If outside vision is not a requirement, various types of structural glass blocks effectively direct light, eliminate glare, and reduce the amount of heat ordinarily radiated into a room by the sun. The stairway in this view leads to the chemical laboratory of the South District Filtration Plant, Chicago. *Photo: Hedrich-Blessing*

sun control by the window itself

Exterior sun control devices can by a logical extension be made to include the actual glass used in the wall opening. Of course, unless special glasses or types of glass installation are used, the window will not exert any control over either solar energy or solar brilliance.

However, various kinds of glass and windows have been developed for sun control. The simplest and oldest, as far as glass goes, is the frosted type which eliminates glare (and clear vision at the same time) but has little or no effect on the incoming heat. Translucent glasses, in general, are effective for room areas where outer vision is unimportant, such as hallways, stair wells, reception rooms, and the like. The more expensive glass block not only does away with glare, but it materially reduces the radiated heat of the sun, dissipating it in the dead air space inside the block. Directional blocks lift transmitted light upward to the ceiling whence it is reflected evenly throughout the room.

However, none of these sight-barring glasses actually serves the major purpose of a wall opening, which is to permit vision out and sunlight in while barring the violences of weather from the occupants of the room and controlling solar glare and radiation. Neither, of course, do the standard window glasses, d/s or plate, which are transparent indeed, not only to visible radiation but also to heat and glare.

heat absorbing glass

An effective method of controlling the summer sun's heat without special devices is by the use of heat-absorbing plate glass. Though its cost is somewhat higher than standard plate, and two to three times as high as d/s, its effectiveness in reducing solar radiation and glare is so great that the higher price is unimportant in the long run. Particularly when used in conjunction with summer cooling systems, these glasses prove a profitable investment, since they cut down the operating costs of the systems noticeably.

Their chief disadvantage is that they are just as effective in barring solar radiation in the winter when it is desirable in the rooms, as in the summer when it is not. Furthermore, this glass is only moderately effective in the summer when installed in a regular single-pane thickness window frame—the reason being that while about five percent of the solar radiation is reflected and 55 percent is absorbed, a good part of the latter heat is reradiated into the room. True, the reradiation is on a longer wavelength which is not as hot or as destructive to materials and dyes as the shorter infrared wavelengths; nevertheless, it is "warm heat." Despite this fact, claims are made that a room provided with a single thickness of heat-absorbing plate will be from 10 to 20 degrees cooler in summer weather than one without it, particularly on the hottest days.

The average heat-absorbing plate glass also cuts out about 30 percent of the visible light of the sun, while still permitting clear vision; this materially reduces glare. Its watery green color is cool-appearing, too; though some clients may not like the slightly atrabilious effect it casts over the landscape. The light-barring factor of heat-absorbing glass must always be considered when scaling wall openings for a certain level of daylighting in the room; for a given level the opening must be at least 30 percent larger than when a plain plate glass is used.

It is obvious from the above facts that, though heat-absorbing plate is moderately effective in single thickness installations in the summer, it is actually detrimental to the solar heating principle in the winter. Consequently the most effective use of this material is in double windows if the winter climate is severe, and in some sort of awning or jalousie installation where heat is the major problem.

glass awnings

Heat-absorbing plate in a projected window frame provides the most efficient sun control window for warm climates or any region in which the winters are not exceptionally severe. A projected frame of the awning type with a height of anywhere from two to four feet, depending on the height of the total window area to be protected, will, when opened out, serve to reduce room temperatures very markedly since the heat reradiated from the inner surface of the glass would be *outside* the building rather than inside. Like any other awning a projected frame can be raised or lowered at will to meet the various angles and intensities of sunlight. Practical daylighting can be achieved with such a window without the intense heat which such daylighting often brings with it.

Where winter temperatures are low, the fact that an awning frame with heat-absorbing glass provides only a single glass thickness means reducing the efficiency of the solar radiation in supplementing the heating system. It could, however, be installed as a permanent storm window, certainly in existing buildings and perhaps even in new ones, if the economics of such a job proved satisfactory. Actually the glass jalousie or the double window would serve the purpose better, though the summer efficiency of these types of windows will not be quite as high as the awning installation.

glass jalousies

In the old days most residences were provided with workable wooden shutters with small movable slats which were used by the occupants to bar the hottest rays of the sun while still permitting a little air to enter. They were also useful protection against rain and snow, and proved a nuisance to burglars, too, when bolted shut.

Today most of the shutters seen on "Cape Cods" and "Dutch Colonials" are phonies. The new house that has usable wood shutters today is eccentric; a reactionary standout against the march of progress. However, the principle of the shutter was always a good one; its major disadvantage was the fact that it killed vision along with solar glare.

Glass jalousies are nothing more or less than a modern dressed-up version of the old-fashioned shutter, permanently fixed in the window opening. They are quite common in the warmer states where intense solar heat is always a problem. Instead of wood slats, narrow strips of heat-absorbing glass are put into a frame which is adjustable from inside the room. When the slats are open, excellent air circulation results inside the room, glare is minimized, and a large part of the sun's heat is kept outside. Furthermore, when correctly slanted, the slats of the jalousie keep out the hardest of rains while ventilating the room.

In the north, glass jalousies could serve as storm windows when used in addition to regular windows; and, since most types are furnished with their own screens, they can be left in place the year round instead of being removed in the spring and put in place again in the fall.

One limitation of the jalousie is, of course, that it interferes with vision to some extent, since the slats give the window a markedly striped effect. However, it is quite true that many clients will like the effect the jalousie makes in a window; and the ease with which one can be adjusted is a distinct point in its favor.

double glazing

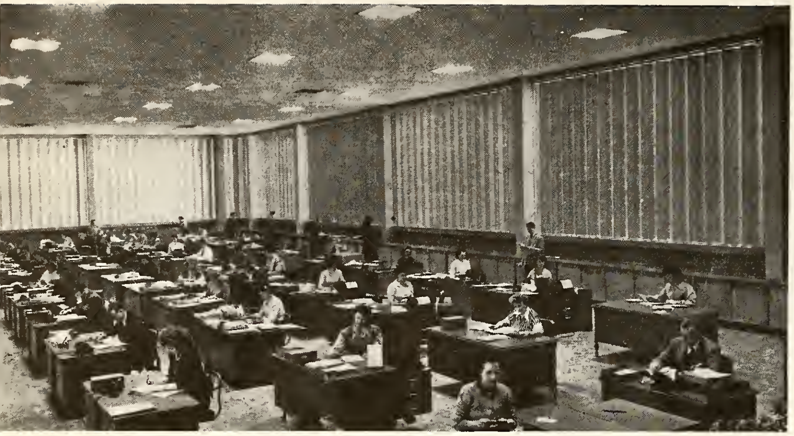
In the long run, probably the single most effective method of sun control the year round in localities having both hot summers and cold winters is the double-glazed window with the outer light made of heat-absorbing glass. Double windows have been sold mainly as effective insulating units for large window areas in regions needing considerable winter protection, and there is no question of their efficiency in that regard. However, when the outer light is made of heat-absorbing glass, the double-glazed window is also effective in the summer as well, though some exterior shading, whether it be trees, awnings, eggcrate overhangs or some other device, will be advisable to protect the interior from the hottest attacks of the sun. Certainly for large commercial, industrial, and institutional buildings in which heating and cooling costs are a major factor, the considerably higher original cost of the double-glazed, heat-absorbing window will soon be amortized by savings in operating the heating and air-conditioning plants the year round.

For residences the same savings also exist, but on a smaller scale. It will often be a matter of deciding whether the savings in operating an all-year-round air conditioner in a solar house will be greater than the capitalized value of the added cost of the double-glazed window over the life of the mortgage. Furthermore, many financial institutions still do not recognize the full economic value of the double window in setting appraisals and mortgage values on new homes, so that often the added cost of such windows has to be paid as part of the cash investment the home owner is required to make.

Double glazing is certainly more valuable in the winter than in the summer, particularly in cold climates. Not only does it cut down the heat loss through large glass openings, but it also eliminates condensation, prevents fogging or frosting on the glass

Glass jalousies are common in the warmer states; clear, obscure, tinted, or heat-absorbing glass may be specified. They can minimize glare, keep out a large part of the sun's radiated heat, permit excellent air circulation, and are easily operated from inside.

Photo: courtesy of Pro-Tect-U Jalousie Corporation



Among several types of inside sun control devices are vertical metal louvers. Those illustrated here are in the general office area of the Guarantee Insurance Company, Los Angeles. *Photo: Waro Studios*

surface, and does away with drafts around the opening which usually result from the cold entering through a single sheet of glass. Perhaps it should be mentioned in this connection that the double-glazed window with the outer light of heat-absorbing glass often has a special value even in winter. Many solar homes have had to be protected by drapes or venetians even on the coldest days: since on a very sunny day, no matter how cold the air, the sun's rays can heat up a room to a nearly insupportable temperature, entirely unassisted by the furnace. The heat-absorbing glass in the outer light of a double-glazed window will, of course, eliminate this unusual hazard.

It seems obvious that were it not for the high cost of the original installation and of breakage replacements, the double-glazed window with heat-absorbing glass in the outer light would soon become standard in all but the most minimum priced buildings.

polaroid windows

This extremely novel window which provides absolute control over glare depends upon the principle of polarized light for its success. For the most part such a window is far too costly for general architectural use, its present applications being limited to airport control towers, trains, or buses, and illumination control filters in art museums and similar locations.

The window comes in two types. One has a fixed single glazing which provides a predetermined intensity of light; this is typically used in air port control towers and also can be effective in window visor flaps or in projected windows, if the high cost can be warranted. The other type is double and provides variable transmission. It is being used currently on a few trains and ships. The inner pane is movable (a limitation being that for effective control the pane must always be circular) and will vary the light entering the area all the way from full value down to blackness.

Data on the heat-eliminating power of this type of installation is lacking; it undoubtedly prevents a certain amount of heat from entering, but if it does not affect the infrared band it will not really create comfortable coolness on the hottest summer days.

inside sun control devices

Methods of controlling solar radiation inside the room are well known and in wide use; they need not detain us long. They include shades, venetian blinds, glass curtains and drapes, and (much more important than often realized) methods of interior decoration. As pointed out previously, few of these techniques satisfactorily control solar heat inside the room—not, at least, without at the same time practically eliminating all sunlight.

shades

Cloth shades, one of the oldest methods of controlling glare and giving privacy, probably provide the least effective method of controlling solar heat in a room. According to Table 1*, they eliminate no more than five or six percent of the solar radiation entering through a window at most hours of the day and in the late afternoon actually permit more to enter, by about five percent, than would normally come in through an unshaded window. These figures may vary somewhat with different types and colors of shades, but they undoubtedly will be of the same order of magnitude whatever the material.

Of course they are wholly effective in controling glare: that is, they eliminate practically all of the light when pulled down. Their only merit is their cheapness and the fact that they require somewhat less maintenance than do venetian blinds. On the other hand their useful life is relatively short, particularly if they are not operated with great care.

Where very low-cost glare control, without reference to radiation control, is desired, as in certain types of schools and other institutional buildings, the double shade, hung across the center of the window, can be effective. One shade pulls up over a pulley, the other down in the normal fashion. It is true that this type of installation calls for nearly hourly adjustment by the supervisor, teacher, or foreman, if it is to be at all efficient but correctly handled it can give any room adequate light on a clear day, while eliminating glare.

In many modern window-walled homes bamboo-strip roll shades are effectively used as interior glare-control devices; these bamboo blinds may also be useful in offices and in institutional buildings. Low in cost and relatively durable, the bamboo strip shade is also an extremely attractive decoration element. However, the fact that it eliminates a great deal of the sun's light, and admits what it does admit in a series of narrow parallel stripes, is a defect in any installation where a high level of daylighting is essential.

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* *From "Heat Gain Through Western Windows With and Without Shading," by F. C. Houghten and David Shore.* Transactions of the American Society of Heating and Ventilating Engineers, *Vol. 47, 1941.*

venetian blinds

Ordinary metal or wood slat venetian blinds are a much more adaptable solution of the glare problem in most buildings. They also are more effective in eliminating heat, according to Houghten and Shore, since they cut out as much as 25 percent of the sun's radiation on a hot day. Nevertheless this actually is inadequate protection against heat, when compared with any exterior sun control device.

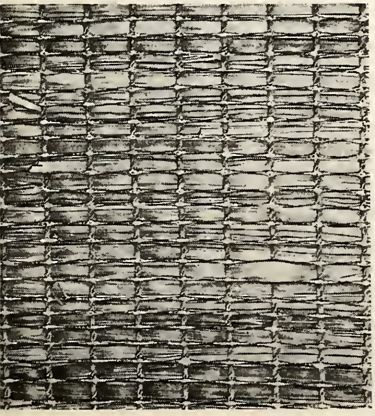
Although the Houghten-Shore table does not include it, the combination of venetian blinds and heat-absorbing glass provides a fairly economical and effective sun control device in the summer months. It is this combination which will be used in the United Nations buildings now being erected in New York (see illustration on page 66. The efficiency is much less than it would be in an installation of double glazing with the outer light of heat-absorbing glass, plus interior venetians; particularly in the winter, the United Nations installation is going to result in high operating costs for the heating plant. Nevertheless, such a combination will provide considerable client satisfaction, especially considering its relative inexpensiveness.

Vertical cloth venetians, developed by Architect Henry Wright, provide effective protection against the sun's glare and serve as a partial bar to its heat, particularly since dense cloths, like drapes, serve to absorb some of the radiation. These vertical venetians are so designed that when pulled back they appear practically the same as any drape. The 5" to 7" cloth "slat," if it can be so termed, can be turned to regulate the entry of the sun's rays as they change angle during the day, by means of an ingenious magnetic device. Though Wright's venetians are noncompetitive with standard venetian blinds, their price is within reach of anyone who is planning to use full drapes made of the usual heavy materials either in a residence or an office.

drapes

Drapes are useful not so much for solar control as for decorative purposes and for privacy. Non-opaque materials, light in color, make the best draperies for sun control purposes, just as glass curtains, which are translucent, most effectively bar solar radiation. Both of these materials admit some light during the day and at night give enough privacy for most purposes.

Drapery materials, of course, suffer from the common complaint of all dyed fabrics: they fade under sunlight. No dyed fabric is absolutely sunfast. A Bureau of Standards rating of 100 hours for a fabric



Above: roll shades of various kinds have long been employed to control the sun's glare. This delicate material found in the office of architects Wurdeman & Becket, Los Angeles, subtly diffuses the light entering a south window wall.
Photo: Julius Shulman

Left: this washable, handwoven, window shade material of royal palm, metallic yarn, and green yarn, was a first award winner in the American Institute of Decorators 1949 Home Furnishings Design Competition. Geraldine Funk, of the Puerto Rico Industrial Development Company, was the designer.
Photo: Samuel A. Santiago

means that it is "good" as to sunfastness. It is a high rating, but none of the technicians will call it "excellent."

Other factors enter as well. Some fabrics tend to wear out faster after repeated washings or dry cleanings than others; some get dirtier much faster than others. No ideal fabric from the points of view of dirt resistance, washability, durability, and sunfastness exists. The best solution is to select a fabric which has good average ratings in these various fields, and is available at a reasonable price.

Some new glass fiber fabrics that rate well in all these respects are now on the market. Heretofore fadability and short life after repeated washings have militated against wide use of these fabrics, despite their high value in fireproofness, insect and dirt resistance, and extreme ease of laundering (glass fabrics in general do not have to be ironed). The new glass textiles are available both in solid and screen printed colors which equal in fade resistance any cotton, wool, silk, or mixed cloths of equal quality. They will resist raveling and breaking—a somewhat common complaint about the older glass fabrics—because of a new method of crimping the fibers in place after they are woven; and will, of course, continue to be fire, insect, moisture, and dirt resistant to a high degree. The price, too, will be competitive with good-quality animal or vegetable fiber textiles for the same purposes. Some combination glass and wool fabrics are already available; they are extremely handsome, and make good drapery materials.

interior decorating

Drapes are only a small part of any interior decoration plan for the control of solar glare. It is surprising how greatly the sharp radiance of the sun can be minimized in any room by careful attention to the surfaces and colors of walls, ceilings, and even floors.

There are two essentially opposite goals to be achieved in glare control: one, in commercial, industrial, and institutional buildings, where the purpose is to *distribute the light evenly throughout the room* with fullest possible efficiency; the other, in residences, where the purpose is to *minimize glare even at the cost of full lighting efficiency.*

Daylighting experts have proved that dark-papered or painted walls have an adverse effect on the efficiency and the health of individuals engaged in occupations calling for high visual acuity. In such buildings light-colored, highly-reflective paints or other finishes will satisfactorily distribute the sunlight throughout the room, and venetian blinds or some other method of reflecting the light from the upper part of a window will throw it as far back into the room as possible, thus reducing or eliminating the need for artificial light along the back wall. Mirrors, picture glass, and other shiny surfaces should be avoided in such rooms, and any glare spots that remain should be veiled, according to George W. Thomas, daylighting consultant to the Truscon Steel Company. In Mr. Thomas' words, "Daylighting is free. Get it into the room in abundance, then control it and use it wisely."

The practical rule of thumb advocated by illuminating engineers, according to Mr. Thomas, is to adjust the brightness of the interior of any room in which close work is being done "so that the ratio of the brighter areas to the brightness of the darker

Draperies of non-opaque materials make highly efficient sun control devices and at the same time provide privacy. Here they are used with heat-absorbing glass in the reception room of the Seismic Exploration Incorporated Building designed by MacKie & Kamrath.

Chalmers-Marvins Photographers

TABLE 1: DESIGN HEAT GAIN DATA FOR SEVERAL WINDOW ARRANGEMENTS ON AUGUST 1, AT 40° LATITUDE; PLAIN 3/16-IN. SHEET GLASS AND WOOD SASH

Sun time	Solar radiation August 1 40° lat. west window	Air to air transmission 95F day	Design radiation gain in Btu per square foot per hour and in percent of design solar radiation intensity on window																	
			West window																	
			Unshaded one light		Outside venetian blind[a] light colored		Shading screen outside dark colored		Inside venetian blind[b] aluminum finish		Inside roller shade[c] dark green		Single light heat absorbing glass (unshaded)		Double glazing			
															Two sheets plain glass		One sheet plain glass and one sheet heat absorbing glass[d]	
	Btu	Btu	Btu	Percent	Btu	Percent	Btu	Percent	Btu	Percent	Btu	Percent	Btu	Percent	Btu	Percent	Btu	Percent
9-10	22	3.0	4.0	18.3	1.9	8.8	1.3	6.0	5.3	24.0	6.8	30.7	3.3	14.8	3.6	16.5	2.9	13.0
10-11	24	6.2	10.5	43.7	9.0	37.5	2.0	8.2	6.3	26.4	10.0	41.7	7.4	30.7	9.5	39.6	6.2	26.0
11-12	25	9.8	15.5	62.1	14.6	58.3	2.7	11.0	7.1	28.2	15.1	60.4	8.3	33.0	14.0	56.0	7.4	29.6
12-1	60	13.0	39.8	66.4	29.3	48.8	7.3	12.2	20.7	34.5	38.8	64.6	26.6	44.3	36.1	60.1	24.1	40.2
1-2	123	15.0	88.4	71.9	39.1	31.5	18.5	15.0	55.3	45.0	83.9	68.2	57.9	47.1	79.7	64.8	53.1	43.2
2-3	180	18.0	153.0	85.0	57.2	31.8	32.8	18.2	106.2	59.0	144.4	80.2	104.6	58.1	138.6	77.0	94.7	52.6
3-4	206	18.0	175.5	85.2	67.6	32.8	48.4	23.5	136.0	66.0	166.0	80.6	120.1	58.3	163.3	79.3	112.9	54.8
4-5	186	17.5	165.9	89.2	62.1	33.4	58.6	31.5	133.9	72.0	153.5	82.5	113.8	61.2	151.0	81.2	104.1	56.0
5-6	120	15.0	123.0	102.5	43.4	36.2	52.0	43.3	98.4	82.0	115.2	96.0	84.0	70.0	114.0	95.0	76.8	64.0
6-7	40	12.2	43.9	109.7	28.9	72.2	27.7	69.2	36.4	91.0	46.0	115.0	32.8	82.0				

a—So arranged as to keep sun off window.
b—Venetian blind slots at 45°.
c—Shade one-half drawn.
d—Double-glazed window—plain glass inside; heat absorbing glass outside.

From Transactions of the American Society of Heating and Ventilating Engineers, Vol. 47, 1941. Used by permission.
Note: Table is incomplete.

areas does not exceed 3 to 1, preferably, and 5 to 1 maximum." "Recommended Practices of Daylighting," issued by the Daylighting Committee of the Illuminating Engineering Society, establishes standards such as this, and recommends methods of achieving good daylighting which should be very useful to the architect who has to cope with this sort of headache.

In residential work, however, other factors may enter. Except in kitchens, sewing rooms, and other areas in the home where close eye-work during the daytime takes place, a high efficiency in daylighting often is not desirable. The psychological effect of low-level light diffusion is more pleasant in such rooms than the bright and highly reflective lighting achieved by glossy surfaces. If a wall or so, or even the ceiling, is decorated in dark tones—particularly if the room has large glass areas—uncomfortable solar brilliance will be considerably reduced, and a restful and relaxed air will result. Similarly, floor coverings of a nonreflecting type, such as carpets, low-toned materials like flagstone, or wood or tile floors finished with a dull wax rather than a high-polish finish, will reduce solar glare at the major source of first reflection.

They will not eliminate glare entirely, of course, nor will they have any pronounced effect on the amount of solar heat entering the room (except psychological—they will *look* cool!). Some sort of sun control treatment at or outside the window will still be required in all south or southwest rooms.

conclusion

Scientific control of solar heat gain and solar glare is an extremely complicated and difficult problem. George V. Parmelee published a study called "Transmission of Solar Radiation Through Flat Glass Under Summer Conditions" from *Transactions of the American Society of Heating and Ventilating Engineers*, Vol. 51, 1945 which contained *44* numbered mathematical equations of astonishing complexity. He was followed by F. W. Hutchinson and W. P. Chapman of Purdue University, whose paper, "A Rational Basis for Solar Heating Analysis from *Transactions of the American Society of Heating and Ventilating Engineers*, Vol. 52, 1946, contained 38 numbered equations, the key one of which read as follows:

$$Q=F\sum_{n=1}^{n=5088}\nabla_n-5088(U_c-U_w)\,(t_i-t_o')$$

"In which 'Q' equalled the annual saving (based on October 1 to May 1 heating season) in Btu due to replacing one square foot of non-transmitting *south* wall with a double glass *solar* window which is 100 percent in the shade (due to roof overhang) *only* at solar noon on June 21 and 100 percent irradiated by noon sun (solar time) *only* on January 21."

From that equation it is obvious that sun control, technically speaking, is not a simple problem! The need for expert technical advice from daylighting engineers and heating and air-conditioning experts on any job above the level of the small private home or the minimum-cost commercial or industrial building is again made clear from these highly complex computations.

The one thing that this review should have made absolutely clear to any architect, however, is that he must never under any circumstances, if he hopes to retain his clients (particularly the large ones with difficult sun control and air conditioning problems), ignore the sun and let its radiations fall where they may. Whether he handles it himself or calls in outside advice, he must meet the sun on its own terms, and control it in accordance with the client's needs.

LIGHTING ECONOMY

In 1938 the first commercial fluorescent lamp was marketed. This event signalized not only a new kind of lighting for office buildings, shops and stores, industrial buildings, and so on, but also heralded the approach of an era of economy in lighting. Also as the air-conditioning industry grew, it became evident that definite savings were possible when fluorescent lighting was combined with this type of environmental control. Samuel Adams Bogen, New York Consulting Engineer, has stated that "when you drew up plans for your latest air-conditioned building, each 100-watt lamp shown on the plans added $20 or more to the cost of the air-conditioning system." In a published article* he proved that "Each time you substituted a 150-watt reflector lamp in a cheap, high-hat fixture, for a 40-watt unit, you added $14 to the cost of the job! Each time you used a 150-watt filament lamp instead of a 40-watt fluorescent lamp, you increased the electrical energy consumption of that job, not by 110 watts, but by 137 watts." He concluded that "Most installations using projector and reflector lamps for interior lighting *cannot be successfully air conditioned regardless of cost.*" Certainly in view of such statements as these, serious consideration must be given to fluorescent lighting in air-conditioned buildings. In her article "Fluorescent Lighting: What Frequency Is Most Suitable?" (*page 350*), Domina Eberle Spencer questions the acceptance of the standard 60 cycle per second operation in lighting circuits for fluorescent lamps. In her opinion, fluorescent lamps, to perform at their best, should be operated at least 50 times as high as the conventional 60-cycle operation. It has been proven that many advantages result from operating fluorescent lamps at higher and more suitable frequencies. As economic savings are possible and as the weight of metal required for the auxiliary equipment can be markedly reduced, there is little doubt that high frequency fluorescent lighting is just over the horizon.

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*Progressive Architecture, *April 1950*

Design for Sight Saving

BY LESSING WHITFORD WILLIAMS*

In a discussion of illumination levels, quality of light, glare, contrast, color of light, and overhead brightness ratios, the author sets down the general principles of design for sight saving. He has included only as much of the complex background as seems necessary for understanding.

There is no question of the architect's desire to design in accordance with human needs; how to do so, however, is another matter. Plenty of thought has been expended on interiors wherein the eyes are put to steady use, yet a great proportion of even the newest designs are deficient in regard to eye health; in some respects, they are seriously inferior to the conventional designs. Until now, there has been excuse for such mistakes; today, there is not. In the past, the welter of conflicting viewpoints that discouraged anyone who tried to penetrate the scientific background of controlled lighting was a fair excuse. Now, practicable areas of agreement are discernible between the different experts, and laboratory tests have been supplemented by controlled experiments involving large groups of school children over long periods of time. These studies have confirmed the validity of present thinking about light, and have done far more. They have demonstrated clearly that environment for seeing has not only an even greater effect on eye health than was generally supposed, but it has also a parallel effect on general health, resistance to disease, and even on the mental activity of children. It very probably has an effect on the adult's mental activity as well.

Of particular significance to the designer is the fact that harmful conditions are not always evident. The trend of research is toward subtler, usually unnoticed factors which are perhaps more capable of harm than obvious ones. Criteria necessary for guidance in design have been developed, and though there are differences in emphasis between research groups, architects can know what to watch for. An attempt is made here to set down the general principles with only as much of the still-complex background as seems necessary for understanding.

It must be borne in mind that conditions for maximum ease of seeing are sometimes the very opposite of those for lighting to create a mood. They are established primarily to facilitate the more severe and long continued visual tasks, as in schoolrooms, drafting rooms, and general business office areas where the effect on the emotions is secondary. Since most of our problems fall between the extremes, it is our professional responsibility to know when and how far we can deviate from best seeing conditions, and when such deviation is legitimate.

illumination levels

Disputes over quantity of artificial illumination are not yet ended, but an architect who follows the recent recommended footcandle levels of the Illuminating Engineering Society will not find himself too severely criticized by extremists on either side. As for daylight, the popularity of large glass areas insures adequate quantity, though the question of distribution is another matter.

quality more important than quantity

Of far greater importance to the designer is the increased emphasis upon quality of light, and the vastly more complete and integrated analysis of what constitutes quality. It is generally recognized, at last, that deficiencies in quality may nullify increased intensity. Significant in this reappraisal of lighting is the shift of attention from glass areas, or lighting fixtures, to the room as a whole. A lighting manual of 1930 mentions brightness contrast and glare, but there is a vast difference now in our understanding of these and other factors which make for quality. We have today a relatively simple list of factors by which the lighting of any space may be analyzed for ease of seeing. They apply equally well to natural or to artificial lighting; in fact, considerable of the recent development was accomplished in the former field.

glare

The harmful effect of direct glare, of course, has long been recognized, but remarkably little was done about it in actual practice. Now we know that even small differences in brightness of areas within the field of view have really serious effects, and that when a visual task is long continued, more extensive use of control methods is required. In artificial lighting, the old diffusing glass globe and the bare fluorescent tube, actually of still greater surface brightness, are replaced by fixtures whose unit brightness at various angles can be obtained from the manufacturer. In the case of natural light, the controls also are familiar: exterior awnings and

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**Partner, Geo. B. Post & Sons, Architects, New York City.*

overhangs, solid or louvered to cut off direct sunlight; interior diffusing shades; venetian blinds; inclined diffusers and reflectors; vertical vanes; and directional glass blocks, to cut off the glare from the sky. Some of these devices project light further into the interior. In some cases, they have required study to avoid excessive surface brightness. In the case of glass block, this has been done by the manufacturer. In the case of louvers, careful design is required, lest the baffle itself be disturbing. As a palliative, the placement of occupants may be arranged so that the light source is not seen. In classrooms or lecture rooms, however, this arrangement may lead to very difficult conditions for the teacher or the speaker who faces the light, and it is not applicable to classrooms for the lower grades or to other rooms in which the occupants move about at their work.

Reflected glare is also a factor to which lip service is freely rendered, but which is too frequently slighted in actual design. Obviously, specular glare may be controlled either by eliminating the reflecting surfaces or by screening the source. The former method is not fully under control of the architect, while the latter is. There comes to mind a "model" domestic science room which was newly lighted to high intensity with eggcrate-bottomed fixtures. The uncontrolled reflections of the bare tubes on the polished metal and glossy enamel of the kitchen equipment should have been a lesson to anyone. Recently, one well-known manufacturer of over-all eggcrate louvers reprinted in his advertising a warning by one of our foremost authorities, pointing out the unsuitability of any eggcrate louvers for classrooms, because they afford no control of reflected glare, although shielding the light source from direct view. Nevertheless, they are dramatic, they photograph well, and because they are fine in the right places we shall continue to see them in wrong places. How many office installations control glare reflected from typewriters? Until shiny pens, rulers, finger rings, and glossy paper are gotten rid of, the safe course is elimination at the source.

Subtler in quality, and therefore still more subject to neglect, is diffused glare. Yet authorities today are emphasizing its great importance. Veiling glare may result not only from reflection of a concentrated source by a reasonably matte surface, but also from a fairly large bright area reflected by a semi-matte or glossy surface. In either case, the visibility of the "task" is enormously reduced. A familiar example in schools is the veiling glare on the left end of a front chalkboard from a window close to the front of the room. The veiling glare may make the writing on the board completely illegible to pupils in the right front corner. This was the basis for the old standard forbidding windows within a certain distance of the front wall. When flexibility demands continuous strip windows in modern design, the chalkboard is best not extended to the corner.

Glare is the extreme form of brightness contrast. Lesser, apparently innocuous contrasts have become subject to control. With increase of illumination intensity or of task duration, contrast control must become increasingly strict. Contrasts between desk top and floor, walls and trim, seem innocuous and perhaps are, at low lighting levels, but their capacity to disturb rises very quickly as intensity is increased. At the high levels regarded by many as minima today, contrasts must be carefully limited.

contrast

Contrast within the task itself, as of black type with white paper, is obviously necessary for seeing. Sensitivity to this desirable contrast increases rapidly with light intensity from one-half to 50 footlamberts, but very little above 100. On the other hand, contrast of the task with its immediate surrounds becomes increasingly disturbing at high light levels, and intensely so with appreciable periods of exposure, thus nullifying the value of the increased light. When the brightness of the area surrounding the task is low, the graph of visual acuity actually shows a downward trend above some 38-40 footlamberts (say 50 footcandles at 75 to 80 percent reflection factor). When the surround is totally dark, it will do so above 7 to 15 footlamberts.

There is fairly general agreement that the adverse effect of contrasts within the background bears some direct relationship to the area of contrast, and an inverse relationship to their distance from the center of the visual field. Authorities differ somewhat as to the importance of these factors. Some hold that small enough areas of fairly sharp contrasts can be neglected; others hold that even these are harmful, particularly over a period of time, and that they retain a considerable portion of their power to hinder vision even at the edges of the field of view. Some, too, would go so far as to limit contrast ratios within the background, rather than merely establish limits of contrast with the visual task, perhaps less for optical reasons than for the psychological one that the eye is distracted and that combating distraction induces fatigue.

When seeing is of real importance, it is only sensible to keep brightness contrasts well within established limits, particularly when in such a case, unlike questions of quantity, no one will claim that this is harmful. In any case, we must be sure that the surrounding areas, within an angle of 30 degrees each side of the axis of sight, are nowhere less than one-third as bright as the task; within the peripheral field, not less than one-tenth. Also, brightness of the surrounding areas should not be greater than that of the task.

In the peripheral field, higher brightnesses are not always avoidable, since a properly diffused light source is apt to require too much area to be kept out of sight entirely. However, since the eyes are particularly sensitive to brightness in the lower portion of the peripheral region, values in that area should not exceed the brightness of the task. Ceiling light fixtures and windows are held to not over 10 times, and the contrast between light source and immediately adjoining surfaces held to a ratio of 1 to 20. These figures are merely limits not to be exceeded; far better has been accomplished. The commonest gross offense is the contrast between an uncontrolled window area and a masonry pier between windows, which involves contrast ratios running into the hundreds. Until practical dark chalks are available, the blackboard in schools is also a difficulty. However, chalkboards are now available in green or yellow, rather than black or gray. Thus they may be kept to no less than one-third as bright as the adjoining surfaces.

color

This brings up the question of color. Color is generally considered to be strictly the province as well as the delight of the architect. When ease of seeing is the concern (particularly in the case of eyes that are immature or impaired), color of the light, of the background, and when possible, of the task, must be chosen with careful consideration of physiological effect. Here again there can be surprises. The lens of the eye is not color corrected, like the camera lens, and so different colors focus at different points. This is quickly seen if equal patches of intense blue, yellow, and red are placed on black cards and viewed at about 20 feet. The red patch will appear to be raised, the blue sunken, and the yellow flush. This being the case, the pleasant blue chalkboard may cause constant strain as the eye tries to focus at apparently different distances between the chalk and the background. Best results are had with the yellow-tan or yellow-green chalkboards. Bluish light, although fatiguing, facilitates discrimination of fine detail work; for this purpose "daylight" lamps, intended to match the blue sky of a clear day when seen through a north window, are recommended, but only for short half-hour periods. For other conditions, and particularly where children's eyes are concerned, light should be yellower, more like diffused sunlight. It was this that led to the development of the new, yellow tones of fluorescent light that resemble incandescent color. It seems probable that improvements to make the spectrum of fluorescent more closely approximate that of natural light as seen by the eye will further benefit vision. The tendency now is to emphasize certain wave lengths.

Another result of chromatic aberration, to touch only the highlights of a subject that grows more interesting every day, is that the color of the immediate surround should be close to that of the task; if the task be white, the surround, if not neutral, should be in the buff-yellow-green range. Perhaps more contrast might be permitted by some authorities near the border of the peripheral zone, in those few cases where we can be sure that the line of sight is not going to shift toward them. However, any really sharp color contrast, even in the background, is a distraction and therefore a handicap.

overhead brightness ratios

There is a school of thought, with widespread backing, which goes much further in the control of overhead brightness ratios. Limiting the brightness ratio between fixtures and ceiling to 20 to 1, in any case militates against recessed downlights and, for serious reading, flush troffers, even if control of reflected glare could be achieved with them. The ideal of the newer school is that the entire overhead area should be one of uniform light, like an overcast sky, unbroken by darker or brighter areas. This has been achieved in artificial lighting of ordinary rooms by luminous indirect fixtures such as glass or plastic bowls or troughs of low-light transmission, or the concentric ring silvered bulb fixture. Where the shape of the room permits, various forms of cove lighting or other indirect lighting from concealed sources have produced conditions of unquestioned quality. Obviously, by this theory, the uppermost part of the walls must be equal in brightness to the ceiling. If footcandles exceed 50 and the ceiling is low, this means a difficult transition to the limited brightness of the lower walls. Also, if the room is long, as in a large office, the bright distant ceiling will extend into the field of view, or cause veiling glare, necessitating vertical fins to shield it. Beams are not suitable for this purpose, as their soffits form dark bands where they are least wanted. As it happens, most, if not all, of the advocates of the "overhead sky" are quite happy with fewer footcandles. An outstanding example of vaulted interior lighting is the famous Fairchild tennis court at Lloyd Neck, Long Island; its shadowless, evenly distributed light of about 40 footcandles was found ideal for difficult map work during the war. The Metropolitan Museum of Art in New York has two fine examples of such lighting, one of vaulted coffers using narrow light troughs V-shaped so as to catch light, the other a translucent ceiling using polarizing panels. Europe has gone much further than we have in the development of translucent ceilings using both daylight and artificial light, but we have many private offices so lighted. Here, it is interesting to note that additional directional light is advocated by many. Of course, during interviews, this is particularly valuable and the diffused light may be reduced or eliminated, an example of the fact that we are talking of principles to be understood, not rules to be followed blindly. Perhaps it will not be too long before luminous wallpaper will be available for ceilings, providing a non-stroboscopic, fully color-balanced light as easily as the sheet materials now produce infrared "light" for radiant heating.

design for ease of seeing

So, the design of lighting for ease of seeing is started not by computing intensities, but by considering the decoration of the room and its entire contents, to the end that any light introduced may be reflected uniformly. Dark areas and shadow producers are avoided, even to the extent of designing cylindrical or lozenge-shape columns at the window wall. In one way or another, window glare is reduced and daylight brought to the far corners. Matte surfaces and furniture placement are planned to reduce the reflected glare, but control at the source is still necessary. After all of these factors have been accounted for, one must then decide on the intensity of artificial light. The relatively high reflectances adopted will contribute to efficiency.

It may be argued that there is no fun for the designer in following so many rules for sight saving. It is true that dramatic chiaroscuro and strong color should be reserved for other spaces where the task of seeing is neither severe nor long continued. But it is also true that we are dealing with broad principles which allow a vast amount of leeway in design, and that the means of applying these principles offer a challenge to the designer. It is certainly a fact that rooms designed pre-eminently for seeing are very pleasant work places; they also afford a desirable contrast to spaces in which more dramatic effects are legitimate and desirable. These facts furnish the best answers to those who complain that functionalism makes all rooms look alike. Furthermore, we know of the staggering percentage of bad eyes today, and it is becoming increasingly clear that at least among the young, general health and physical growth are also affected by eye strain.

As such is the case, it is hard to find excuse for the type of designer who insists upon using dark woodwork and vivid color in an elementary classroom, because he can't overcome the urge to use them—or perhaps because there aren't enough other jobs in the office where they would be legitimate—and then justifies his callousness by saying it is done to stimulate the children. There is no question whatever that children work better and are better off when the room is designed for sight saving. If children need further stimulation, it is better to call the doctor or improve the teaching. This is one case where no one can object to functionalism. Human eyes have endured too much for too long, and we have only one pair to last a lifetime.

Hospital Lighting

BY HOWARD HAYNES*

Lighting requirements should be constantly considered during the designing of a hospital. A neat clean appearance and ease of maintenance are factors more important in hospital lighting than in the lighting of other interiors. Hospitals emphasize cleanliness—and a lighting system of simple, neat design can add much in creating this impression. Lighting fixtures must be washed and cleaned, not only to maintain lighting efficiency but also, more important in hospitals, as part of the regular routine of keeping all surfaces clean. The cost of cleaning fixtures can vary considerably, depending on the types used. A few extra dollars spent to obtain easy-to-clean lighting units may save many times that amount during the life of the fixture.

To meet these requirements, a variety of fluorescent and filament fixtures are available. For general lighting, the trend seems to be toward recessed ceiling fixtures covered with diffusing plastic or glass, flush with the ceiling; either fluorescent or filament lamps can be used.

comfortable lighting

To achieve comfortable lighting sharp differences in brightnesses within the field of view must be avoided. Lighting units must not be too bright and bare lamps must, of course, be shielded. Often overlooked is the bare lamp brightness as reflected from specular metal or glossy paint; mat, rather than glossy, paints should be used. Floors should be relatively light in color; walls should have pleasing colors and reflect about 50 percent of the light; ceilings should reflect even more but need not necessarily be white. Good lighting fixtures alone do not assure comfortable lighting—the whole interior of the hospital must be taken into consideration in designing the lighting.

amount of light

No matter how clean and sanitary a hospital may be, dim lighting can create the opposite impression. But even more important than appearances, it has been shown that for quick, accurate, easy seeing, certain levels of illumination are required. These values vary, of course, with the difficulty of the seeing task. The footcandle recommendations for the various elements in a hospital plan are listed in the table accompanying this article.

Hospital lighting must satisfy the needs of at least three groups of people—the patients, the hospital staff, and the visitors. The patients, unless they are well enough to read, want low-level, comfortable lighting. The staff, on the other hand, requires higher levels of illumination to permit quick, accurate seeing. The visitors would like to find the hospital a warm cheerful place, and lighting can do much to give this feeling.

fluorescent or filament lighting?

Either fluorescent or filament lamps can be used in most locations. For simplicity, lowest initial cost, and low maintenance cost, filament lamps can be recommended. Fluorescent lamps are more efficient: less heat is generated and the surface brightness is relatively low. As for over-all cost, when lamps are operated many hours per day and/or the electric rate is relatively high, fluorescent lamps are generally preferable. In the past, the principal objection to the use of fluorescent lamps in hospitals was the color they produced. The lamps were deficient in red and people under them looked less healthy than they really were—psychologically bad in hospitals. However, recently developed fluorescent lamps that radiate red light give complexions a more natural appearance. As this is accomplished at some sacrifice in efficiency, their use is recommended only for patients' rooms, operating and examining rooms, and in the cafeteria and dining room. Eventually they may be used more generally.

emergency electric power

Failure of the electric supply in a hospital can well be a matter of life and death; an emergency supply is imperative. Unless the emergency source has sufficient capacity to take on the requirements of the entire hospital, certain lights throughout the hospital should be put on a special circuit that is controlled by the auxiliary power supply.

operating rooms

Good lighting is essential in surgery where a life may depend upon the ability of the surgeon to see clearly. Because the surgeon may be looking deep into a cavity of low-reflection factor, he should have a lighting intensity of 1800 footcandles or more. This light must come from several wide-angle directions to decrease the shadows from the surgeon's head, his hands, and the surgical tools. Heat-absorbing glass filters are used to reduce the radiant heat and provide color correction. A system of concentrating lens plates mounted in the ceiling is also available. The choice of which of the several available operating lights to use can best be left to the surgeons.

The operating light should be supplied by a branch circuit independent of all other lights, and this circuit should be connected to the emergency bus. An automatic throwover switch should be provided to connect the operating light directly to the emergency supply in case of failure of the main power supply.

General lighting in operating rooms has sometimes been neglected. Occasionally a surgeon will insist that he can see better without the general lighting, but when he says this it can be assumed that his general lighting system undoubtedly gives light of poor quality and low quantity. A good general lighting system providing 50 footcandles of light will increase the surgeon's comfort, since it will reduce the contrast between the operating area and the surrounding area. The operating staff will have good light to see quickly and easily in carrying out the instructions of the surgeon. Fixtures built into the ceiling—covered with glass or plastic and flush with the ceiling—are being widely used in modern construction. Either filament or fluorescent lamps may be used. Cool, white fluorescent lamps give a pleasant color that approximately matches the hue of the color-corrected operating light; they also give the anesthetists an excellent idea of the true coloring of the patient's face and lips.

Outlets should be provided for portable operating lights which may be used by the surgeon. All lighting fixtures and electrical

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* Lamp Division, General Electric Company, Nela Park, Cleveland, Ohio

Figure 1—the concentric-ring fixture with silvered-bowl lamp blends well with the ceiling. Fort Hamilton VA Hospital, Brooklyn, N. Y.

Fort Hamilton photos: Martin Helfer

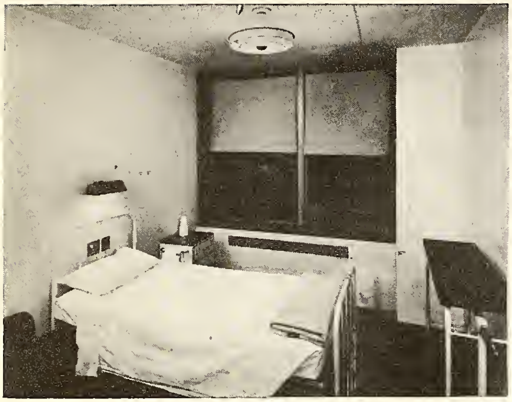
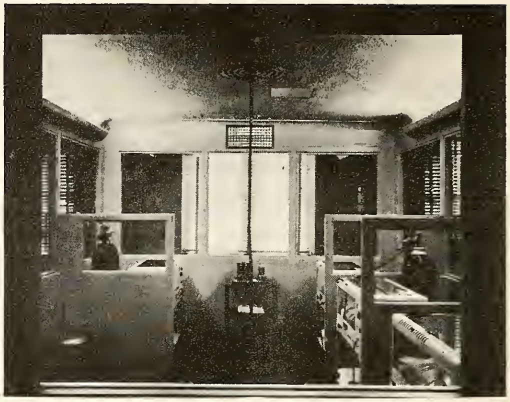


Figure 2—this premature nursery is comfortably lighted to a level of five footcandles by coves containing continuous rows of fluorescent lamps. George Washington University Hospital, Washington, D. C.



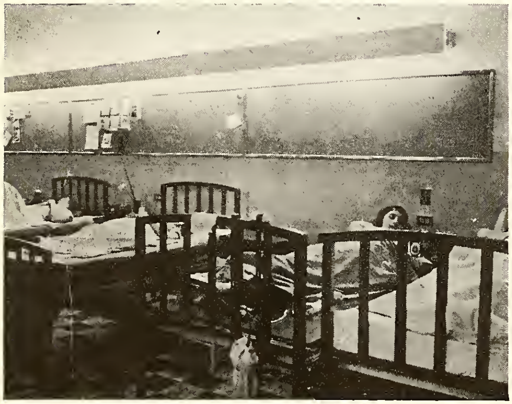


Figure 3—lighting in a children's ward. There are two rows of fluorescent lamps behind the shield above blackboard. Rainbow Hospital, Cleveland, Ohio.

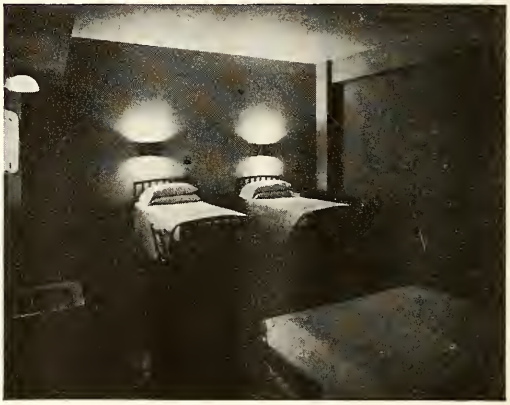


Figure 4—many architects prefer to dispense with ceiling fixtures in patients' rooms; the upward component of light from the bed lamps supplies the general illumination. George Washington University Hospital, Washington, D. C.

fittings below the 5′ level must be explosion-proof because of the danger of igniting anesthetic gases. (*For additional data refer to "Safe Practice for Hospital Operating Rooms, 1950," by National Fire Protection Association.*)

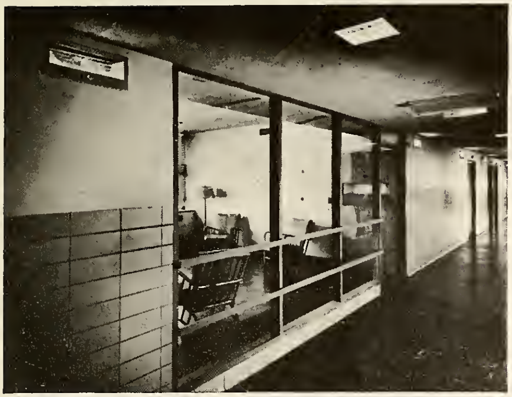
air disinfection

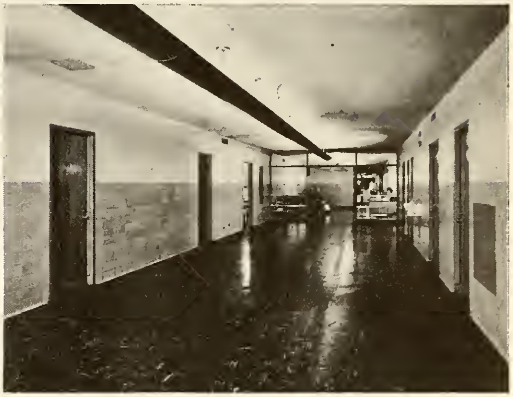
The Council on Physical Medicine of the American Medical Association recognizes the value of ultraviolet air disinfection in reducing the known high concentrations of airborne organisms in hospitals. Germicidal lamps should be used only in fixtures specially designed for their use. Only louvered germicidal fixtures should be used in patients' rooms where there is continuous exposure of patients, and where the ceiling height is 10′ or less. Germicidal units should be installed in the nursery, in the operating rooms, and in the contagious disease wards, if not throughout the entire hospital.

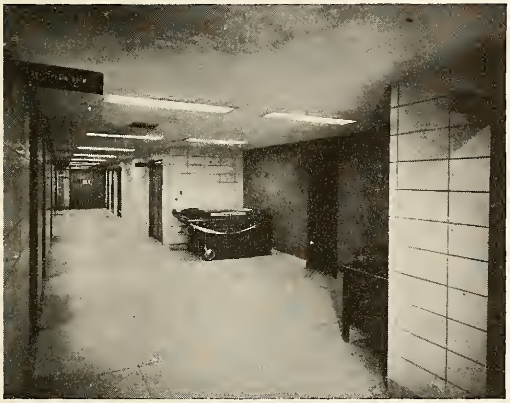
In the operating room of the Fort Hamilton VA Hopsital the fluorescent lighting fixture over the doors contains germicidal lamps for irradiating the upper air without exposing the people in the room to the ultraviolet radiation. The four germicidal lamps recessed into the ceiling on either side of the surgical light can be used to clean the air in the operating room between operations (while the room is unoccupied) or can be left on during brain operations and thoracoplastics by shielding

Figure 5—isolation-ward corridor looking into solarium. Two 60-watt tungsten filament lamps in each recessed louvered fixture provide an average of approximately 10 footcandles. A 15-watt filament lamp in each unit is for night lighting. Fort Hamilton VA Hospital.

Figure 6—the corridor and reception room in the dental section are comfortably and adequately lighted to a level of 10 footcandles with two continuous rows of fluorescent lamps in an indirect fixture. Fort Hamilton VA Hospital.







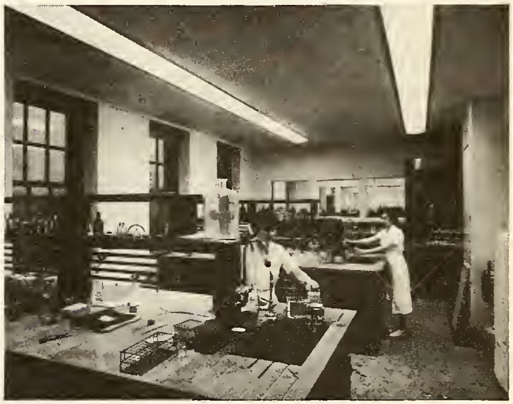


Figure 7—this surgery corridor is exceptionally well lighted, an average of 40 footcandles, with recessed fixtures containing two 40-watt fluorescent lamps. Fort Hamilton VA Hospital.

Figure 8—this chemistry laboratory is well lighted to a level of 50 footcandles. Two rows of 8′ cool-white slimline-fluorescent lamps are used in each fixture. Glass coverplates diffuse the light. St. Francis Hospital, Hartford, Conn.

the face of the surgeon and his staff from the rays of the lamps (page 327).

patient's room

Four lighting requirements should be considered in the patient's room; they are: general lighting (5 footcandles); a light for casual reading (20 footcandles); an examining light for the doctor (100 footcandles); and a night light giving a fraction of a footcandle. Sometimes four different fixtures are used to meet the needs and at other times two or more of these lighting requirements may be built into one fixture.

In considering the general lighting, it is well to remember that, to the patient, the wall at his head is the "ceiling" and the ceiling is a "wall" which he is facing. To provide him with the most comfortable general lighting possible when using a ceiling-hung unit, it is necessary that the fixture brightness, as seen by the patient, be nearly the same as the brightness of the ceiling surrounding the fixture. This rules out enclosing globes and recessed fixtures, as being too bright, and totally indirect fixtures, as being too dark against a bright ceiling. Fixtures of plastic or glass are available that meet the requirements. Perhaps the simplest fixture that approaches the requirements is a silvered bowl lamp with concentric-ring louvers (*Figure* 1).

Cove lighting can be designed so that it will give very uniform and pleasant general lighting (*Figure* 2)—particularly when in-lighting (*Figure 2*)—particularly when instant-start, warm-white fluorescent lamps are installed in such coves. However, cost generally rules out cove lighting. A simplification of cove lighting would be a modified form of the fixture used at Rainbow Hospital in Cleveland (*Figure 3*).

Many hospitals prefer to provide the general lighting by units on the wall behind the patient. In such cases, a reading light is generally incorporated into the fixture, thus making one fixture serve two purposes. Such a solution, however, fixes the position of the beds—which is considered objectionable in some hospitals.

For casual reading, 20 footcandles of light is adequate. In the few hospitals where the patient does prolonged reading before being discharged, a level of 30 footcandles is required.

Where there is more than one patient in a room the light from the reading unit should be well controlled—confining the light, as well as possible, to the patient's bed (*Figure 4*).

Many reading lights are attachable to the head of the bed. These units are simple and generally adequate, but the maintenance cost of repairing frayed lamp cords and broken lamps can be high.

Floor stands give a homelike atmosphere, but as such a light might annoy other patients in the same room it should be considered for private rooms only. Maintenance cost of floor stands is usually high.

Sometimes the patient's reading light can be moved or taken apart to give the doctor a small examining light. In other cases a special examining light can be kept in a nearby closet.

A 25-watt filament lamp in a wall-recessed unit, mounted 18 inches above the floor and provided with a lens or louver to direct the light downward, is generally used for the night light. Another method of providing night lighting, is to have an additional low-wattage lamp in the general lighting fixture. The night light should be shielded from the patient's eyes and it should be located to avoid distracting shadows.

Mercury switches are suggested for use in the patient's room to reduce noise. An automatic door switch on closets is a worthwhile refinement.

As the ceiling is a "wall" to the patient, it would be logical to paint the ceiling a pale color—as long as its reflection factor is kept above 50 percent.

corridors

The intensity of light in the corridors outside the paitents' rooms should be approximately five footcandles, to blend with the general lighting in the patients' rooms. Care must be taken that no corridor lighting fixtures are visible to patients in their beds. Corridors are frequently lighted with units recessed into the ceiling and containing one or more filament lamps. Very pleasant corridor lighting is obtained with a continuous row of slimline fluorescent lamps operating at 200 milliamperes. Crosswise louvering is used. While this system gives a higher lighting level than suggested above, it is a very comfortable system and worthy of consideration. (*Figures 5 and 6 illustrate corridor lighting at Fort Hamilton VA Hospital.*)

Night lights should be provided in the hall. With recessed fixtures in the ceiling it is a simple matter to have an additional low-wattage lamp in each unit to serve as a night light. If fluorescent lamps are used for the regular hall lighting, a separate system of night-lighting units may be required.

Corridors in other locations in the hospital can take higher levels of illumination (*Figure 7 and nurses' station, p. 327*).

nurses' stations

For reading charts, writing, and performing miscellaneous duties, the nurses should be provided with a general illumination of 30 footcandles. (*Excellent lighting of a nurses' station is illustrated on page 72.*)

laboratories

Here the work is of a precise nature and the laboratory workers must be able to see easily and efficiently to achieve accurate results. Thirty footcandles of lighting should be the minimum. There should be 50 footcandles on the table (*Figure 8*) and special provisions for 100 footcandles for such difficult seeing tasks as the reading of pipettes, burettes, etc. Daylight color or quality of light is desirable for colorimetric measurements.

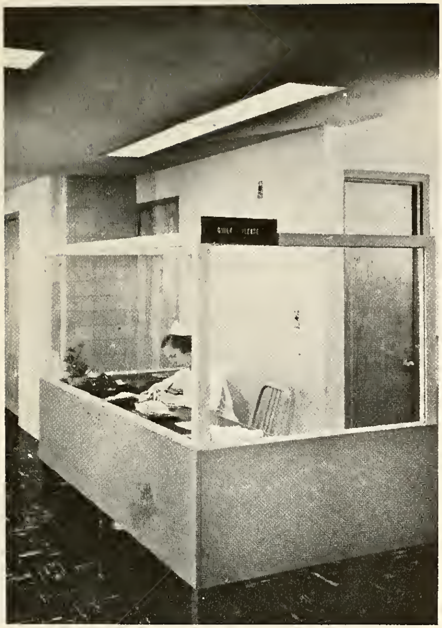
offices, laundries, kitchens, etc.

These areas should be lighted to a minimum of 30 footcandles, with good office- or industrial-type lighting units and in accord with the practice for office and factory lighting. In selecting fixtures, it should be recalled that the psychology of sanitation carried out elsewhere in the hospital has some influence in these areas.

In offices where difficult seeing tasks exist (auditing and accounting, business-machine operation, transcribing and tabulation, bookkeeping, drafting, designing), a lighting installation providing 50 footcandles is advisable.

RECOMMENDED FOOTCANDLES (maintained in service)

Autopsy room:	General lighting	30
	Autopsy table	200
Consultation rooms:		30
Delivery rooms:	General lighting	50
	Delivery table (normal deliveries)	200
Emergency rooms:	General lighting	50
	Supplementary	200
Examination rooms:	General lighting	50
	Supplementary	100
	X-ray and Fluoroscopy	10
Kitchen:		30
Laboratories:	General lighting	30
	Supplementary on work tables	50
	Close work	100
Library:		30
Nurses' stations:		30
Offices:		30
Patients' rooms:	General lighting	5
	Supplementary for casual reading	20
	Supplementary for examination	100
	Corridors	5
Pharmacy:		30
Solaria:		30
Sterilization rooms:		30
Surgery:	General lighting	50
	Operating table	1800
Therapy:		30
Toilets:		10
Utility rooms:		30
Waiting rooms:		20

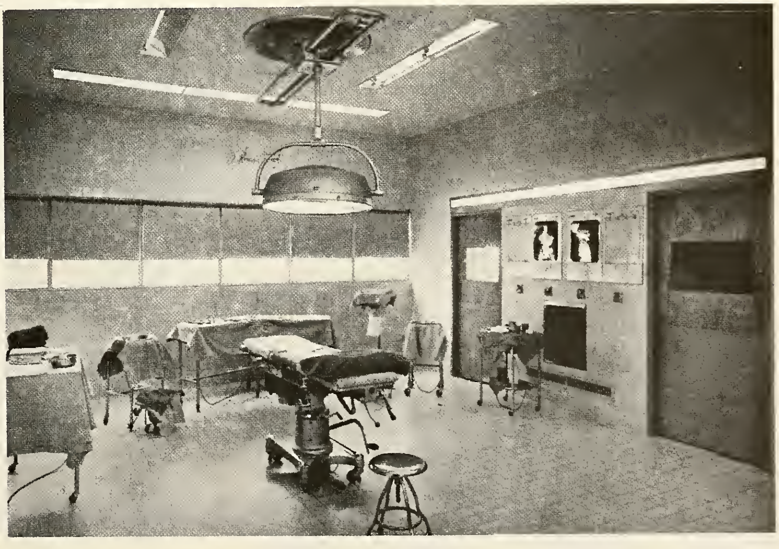


VA Hospital: Brooklyn, New York

Skidmore, Owings & Merrill

A general illumination of 30 footcandles provides adequate lighting for duties to be performed at the nurses' station.

Fluorescent lighting fixture mounted flush over doors on side wall contains germicidal lamps for irradiating upper air. Four germicidal lamps are also mounted on four sides of the surgical lamps. Photos: Martin Helfer



Lighting as a Factor in Office Economy

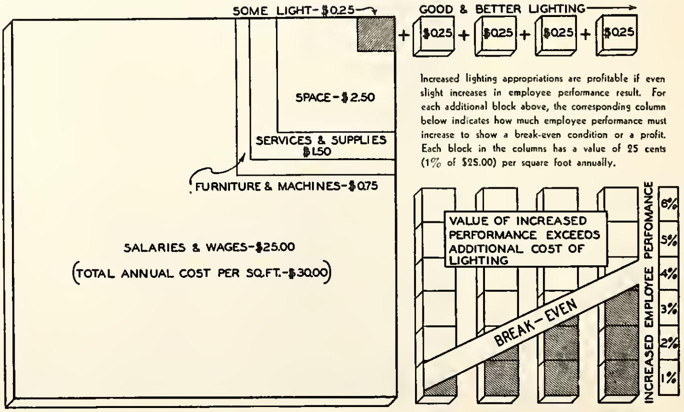
BY R. L. OETTING*

Cost naturally and inevitably affects the selection of a lighting system for any office. When the questions "How much light?" and "For what purpose?" are asked, the answers are always found in solutions within a limitation of cost. If sensitivity to cost intrudes too strongly, the real economy may be lost. Conversely, the lighting dollar can be spent more effectively when lighting cost is considered in its proper relation to other expenditures; the return on many of these may be affected by the relevance of the lighting.

Every office requires some light; if that amount were limited to the lowest value for "just barely seeing," very little would be needed as only a fraction of a footcandle is essential for most tasks. All will agree, however, that such an amount would place a tremendous burden on the eyes and its effect would be reflected in larger elements of office cost, to say nothing of personal sacrifice and possible permanent harm to eyesight. A constructive view of wise spending would show that so small an amount of light would contribute only to hazard; no one would willingly create hazard and expense by placing this limitation on seeing. Yet, there are some who often take lighting for granted and assume, if no protest is made, that any amount of light is satisfactory. Such indifference not only is expensive, but prohibitively so. A brief analysis will show the contribution of simple improvement in lighting to larger items of the office budget.

The operation and maintenance of a system which gives "some light" will be at least 25 *cents* per square foot annually. Although many inefficient installations now in use actually cost twice as much, the lower value will be considered. The object of lighting is to serve the office personnel who represent a cost of at least 25 *dollars* per square foot annually. It is obvious that if better lighting would produce but small increase in employee performance, the increased value of dollars paid in salaries and wages would be sufficient to justify a several fold increase in lighting cost.

Presented pictorially below, increased expenditures for good and better lighting are offset by a 1 to 4 percent increase in employee performance. Increases of 2 to 5 percent or more for the respective lighting costs are actually *profitable.* The benefits are greater than represented due to the increased return on fixed expenditures for space, services (telephone, telegraph, etc.) and supplies, and furniture and machines. Gains in employee performance exceeding 5 percent are not uncommon.



Increased lighting appropriations are profitable if even slight increases in employee performance result. For each additional block above, the corresponding column below indicates how much employee performance must increase to show a break-even condition or a profit. Each block in the columns has a value of 25 cents (1% of $25.00) per square foot annually.

Analysis of economies derived from good office lighting. This chart is based on a typical distribution of annual office expenses; costs are related to a square foot of space.

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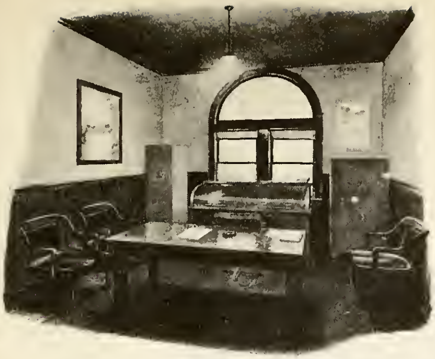
*Engineering Division, Lamp Department, General Electric Company

1. correlation of lighting and surface finishes

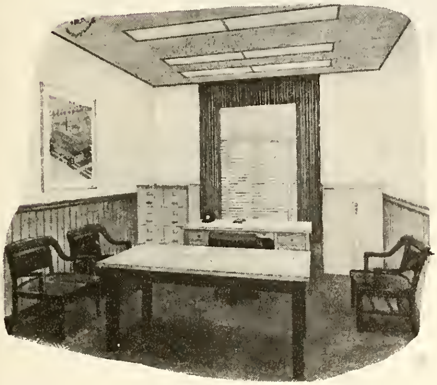


Left: care in the treatment of room surfaces, as well as with lighting equipment and design, is essential for comfortable seeing conditions. An old office is useful in pointing out the importance of correlating lighting and room surfaces for improved seeing; a feeble but glaring light source, an unshaded window, dark walls and ceiling, darker furniture and carpeting express discomfort. The occupant may escape window glare by turning his back on it, but he will immediately find the reflected glare from the dark, shiny table top intensified by the generally dark environment.

guide to desirable reflectances

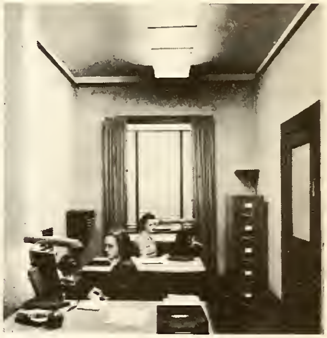
Ceiling	80% or more
*Walls**	50-60%
Desk tops, furniture, equipment	30-35%
Floors	20-30%

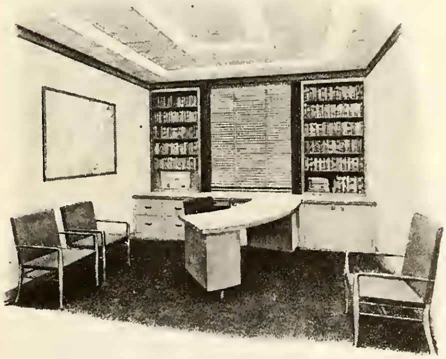
*Should appreciably darker finishes be employed for decoration, they should be used only on walls not generally in or adjacent to the working field of view.



Left: modernization of this office on any scale will have comfortable seeing as its objective. In replacing the ancient light source with a recessed troffer system a major step has been made towards comfort. It would fall far short of its goal, however, if light, high-reflectance, mat-finish surfaces were not substantially building up efficiency and appearance values. Appearances have been thoughtfully considered in this modest plan. The venetian blind treatment not only eliminates daylight glare, but "keeps light" from the artificial system within the office. A visual slot is desirable in treating windows, however, so that psychological advantages of looking out are preserved.

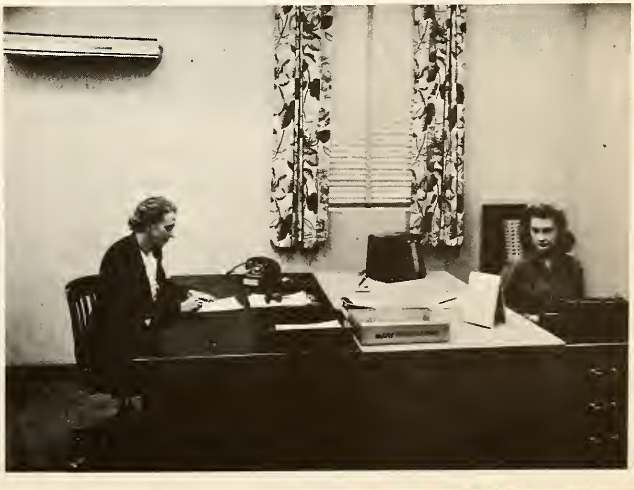
Below: a practical harmony of objectives is realized in this small office. A simple general lighting system, provided by the ceiling units, is given heightened efficiency and appearance by the selection of room finishes of recommended reflectance. The raised copy holders with their well-designed supplementary units greatly increase the visibility of the typists' copy. The light colored desk tops and other surrounding surfaces eliminate the possibility of unsatisfactory brightness patterns which result when illumination is not balanced in quality and quantity.



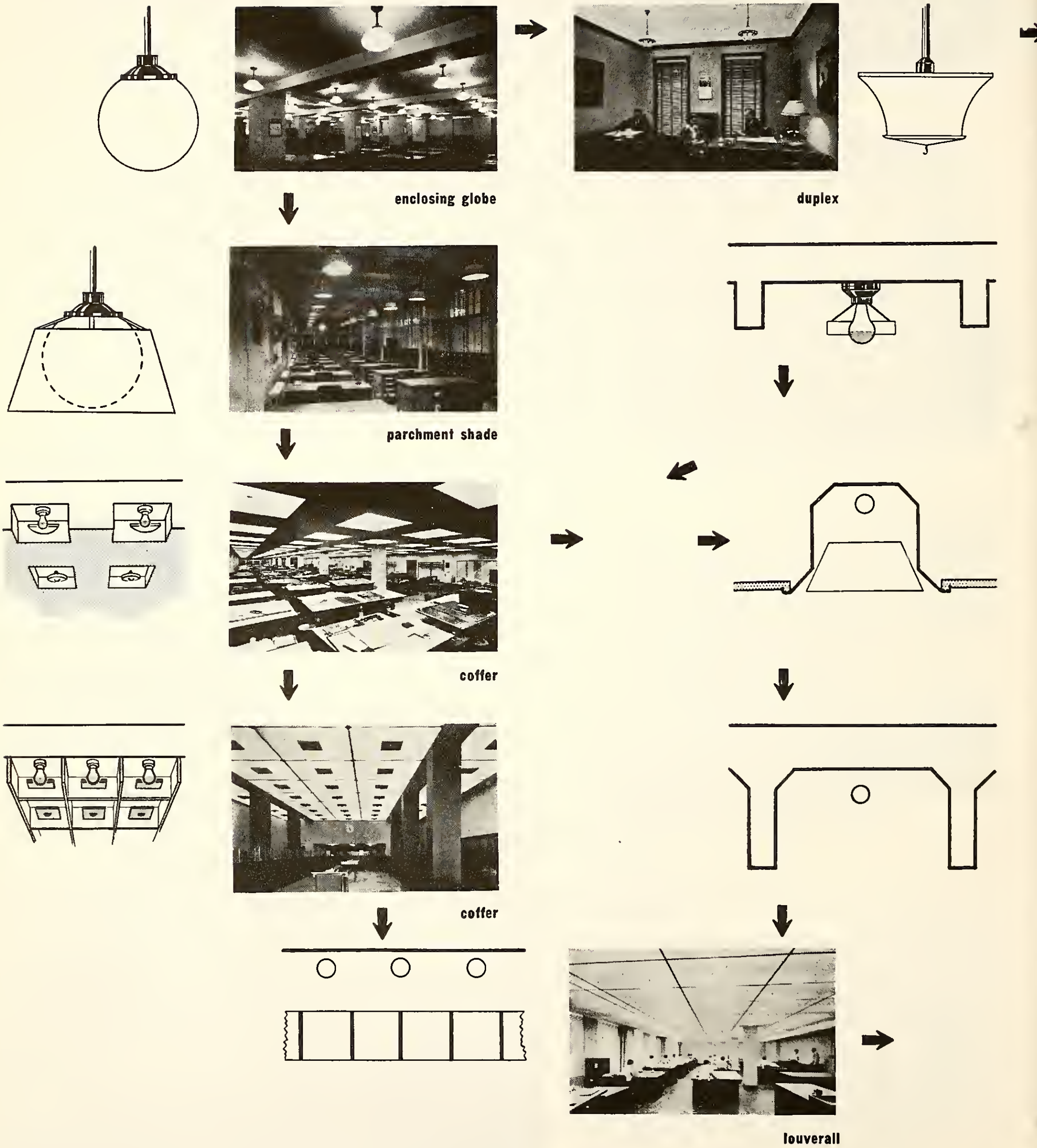


Above: remodeling plans for an old office, to the potentials of form and efficiency provided in lighting today, can achieve superior appearance values. The troffer system is employed in a distinctive pattern and effectively delivers illumination for all purposes. It is balanced in character by the light-colored room decorations and furnishings. In the clean-cut composition of the ensemble, the concern for seeing was the objective that shaped the ultimate result.

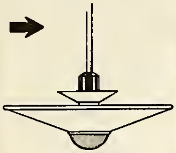
Right: it is well to observe the way the light-colored desk "fits" into the office environment. Essential for comfortable seeing at the more effective lighting levels, light-colored finishes also contribute to the clean simplicity of good office design. Conversely, the dark desk clashes with its surroundings and accentuates the relation between the white paper of the task and the surrounding area.

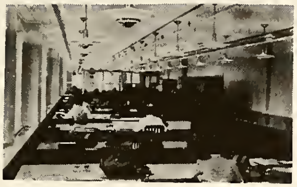


2. the evolution of quality lighting

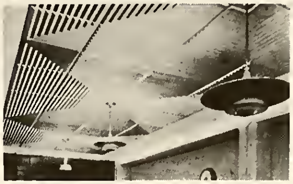


The sequence of systems indicated by the directional arrows roughly approximates a series of developments that lead from enclosing globes to present-day louverall ceilings. The advance of ideas in incandescent filament systems, from enclosing globes to parabolic ceiling sections and to the refinements of coffer lighting, prepared the way for fluorescent systems. Thus the troffer was the natural fusion of ideas represented by the parabolic trough and the coffer. As illuminants have improved, objectives in quality and quantity have risen. Techniques to realize these objectives have closely followed the opportunities presented by improved light sources.

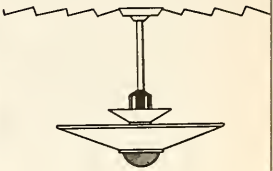


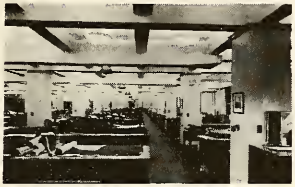


silvered bowl

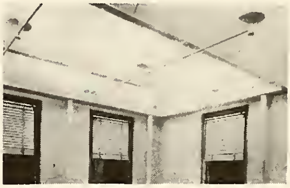


parabolic sections

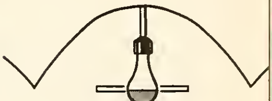


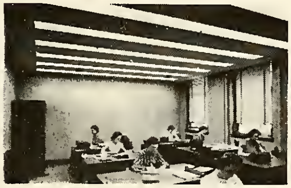


beamed ceiling

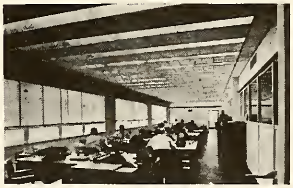


parabolic troughs

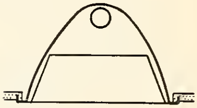


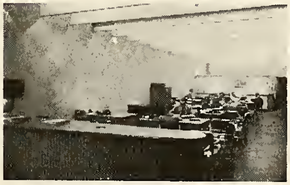


white troffer

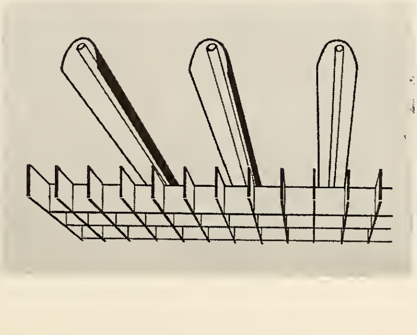


aluminum troffer



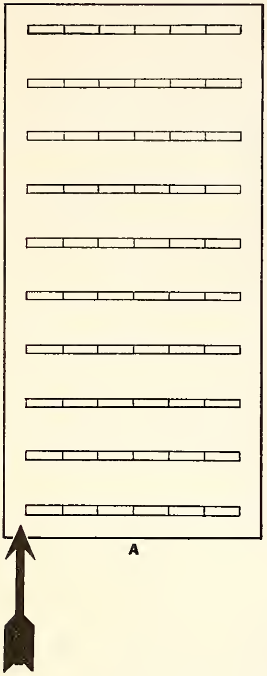


plaster



future louverall

3. disposition and orientation of fluorescent luminaires

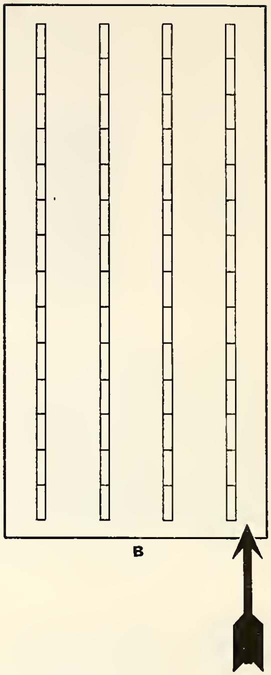


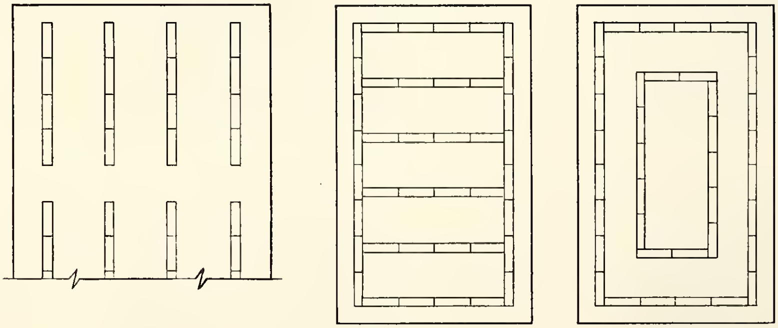
1. appearance

Long lines of plan B tend to give an unpleasant "bowling alley" impression. This effect is accentuated by sharp demarcation of brightness when units are mounted too close to ceiling or recessed as troffers. In addition, irregularities in suspension and alignment are more readily noticed. Plan A minimizes these disadvantages while retaining the value of continuous-row technique. With either plan A or B, the heavy effect of low mounting should be avoided.

2. comfort

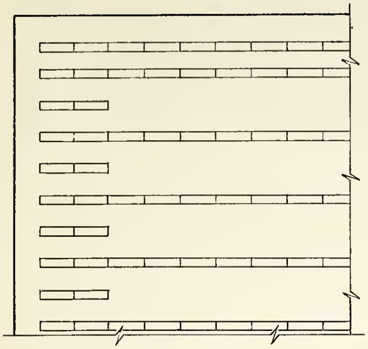
Best use of troffers and most luminaires with opaque sides is found in plan A; units or rows of them are placed perpendicularly to the predominant direction of view. Luminaires with light-transmitting sides should not be used in transverse mountings because, in perspective, the sides form a continuous ceiling effect. When the transmission results in panel brightness of more than 200-400 footlamberts, it is essential that the orientation of plan B be followed.

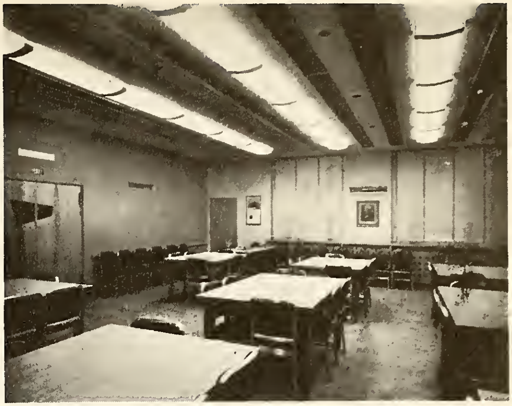




3. patterns

Intermittent rows at left break up converging-line pattern of plan B. They are superior to individual luminaires which produce a "forest of fixtures" effect and require a power outlet for each unit. Combinations of plans A and B result in patterns suggested above. These produce uniform brightness effects on all walls, avoiding scallops which are objectionable to some. Patterns should be used only if equipment is low in brightness.

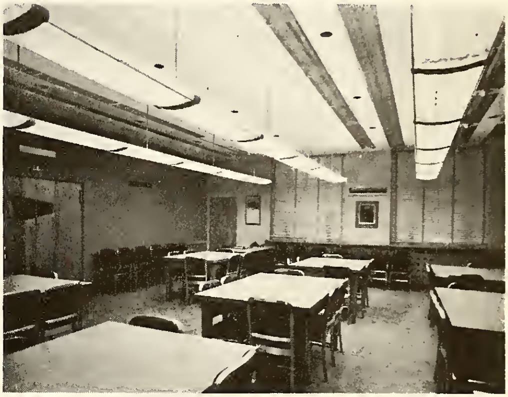




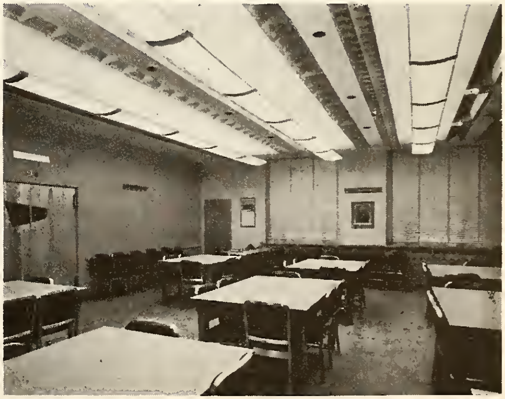
Above: "bowling alley" effect accentuated by sharp demarcation of brightness when lighting units are mounted too close to ceiling.

4. illumination

In addition to other advantages, plan A often permits a closer approach to a chosen quantity of light. The addition or subtraction of a row has much less effect than in plan B. Refinements, aimed at a more uniform distribution of illumination, are suggested above. Personnel in perimeter areas are often penalized in quantity of light, or, if walls are dark, in direct quality. Concentration of units as illustrated will alleviate these conditions.



Above: heavy effect produced by low mounting.
Below: lighting units hung at proper distance below ceiling for optimum lighting.



5. reflections

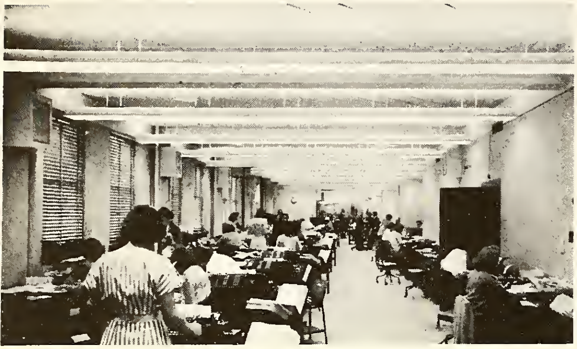
The use of mat-finish, light-colored surfaces on office furniture and equipment eliminates the occurrence of lamp, fixture, and window reflections. The trend toward these finishes is permitting a freer choice of lighting equipment. In wood finishes, a combination of rubbing and grain may develop a directionally selective reflection effect. Sources imaged perpendicular to the desk are often sharp, confined; those parallel are fuzzed out, indistinct. This result recommends the use of lighting plan A. Other considerations regarding the reflectance and surface characteristics of finishes are in Section 1, entitled "Correlation of Lighting and Surface Finishes."

6. direction of view

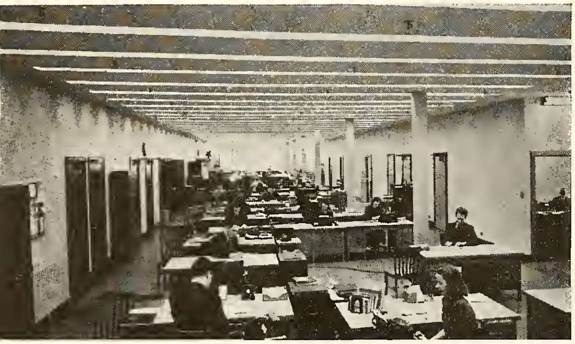
"Long views" are desirable psychologically to give maximum feeling of space, and physically to assure muscular relaxation of the eyes. Relaxed distant vision requires 15-20 feet. Work flow and supervision often suggest the indicated orientation of personnel.

4. comfort and appearance with economy

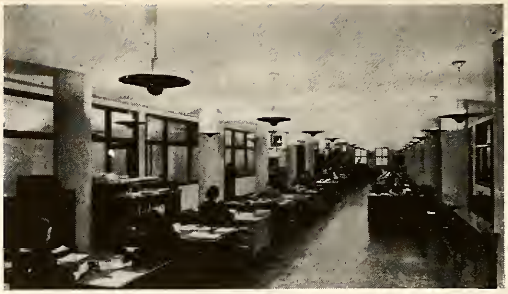
These examples represent the types of lighting systems and equipment employed in good practice today. Legends present considerations which assure maximum satisfaction from each and indications of typical costs per square foot annually. Symbols—L: lamps; E: energy at $0.03 per kwhr; C: three cleanings annually; A: amortization at 16⅔ percent; T: total. Annual use, 2800 hours.



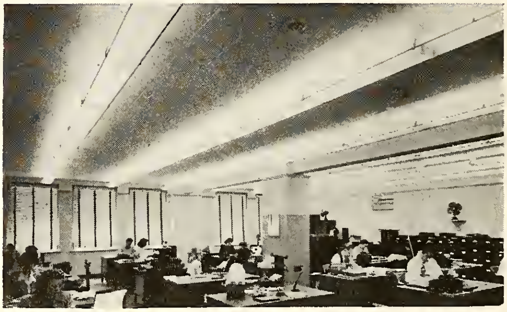
Above: 50 ft-c; L:$.07; E:$.30; C:$.09; A:$.25; T:$.71. Direct-indirect units with opaque side panels generally give greatest comfort at right angles to the direction of view. The appearance limitations of apparently converging rows is also avoided. Direct-to-ceiling mounting is satisfactory only with closely spaced units designed for such use. Again, suspensions should be chosen to keep the system a part of the structure and as far out of the visual field as practicable. Single stems are adequate and preferable to the design shown.



Above: 50 ft-c; L:$.06; E:$.26; C:$.09; A:$.30; T:$.71. Troffer systems are neat, functional, and rate high in appearance. Light-colored room and furniture finishes improve appearance by reflecting light to the ceiling between troffers. For comfort, the units should yield lamps crosswise to at least 40 degrees and present very low brightness in usual viewing directions. Comfort and appearance indicate rows at right angles to the line of sight. With no indirect component, troffers must be closely spaced to avoid sharp, deep shadows at the work; aims are best met by troffers in continuous rows not more than four feet apart.

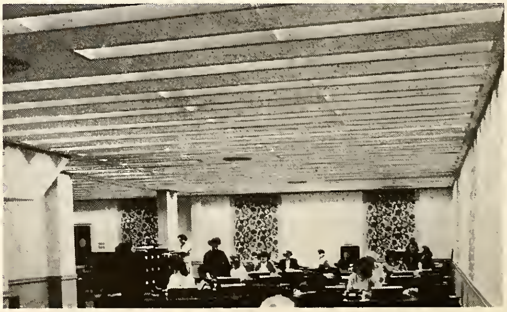


Above: 35 ft-c; L:$.06; E:$.62; C:$.02; A:$.05; T:$.75. Initial fixture cost is low for indirect and semi-indirect filament units. Limitations of heat, cost of operation, and wiring restrict illumination to less than 40 footcandles; fluorescent units are less limited by these factors. In large areas ceiling brightness may introduce discomfort at levels much over 50-60 footcandles.

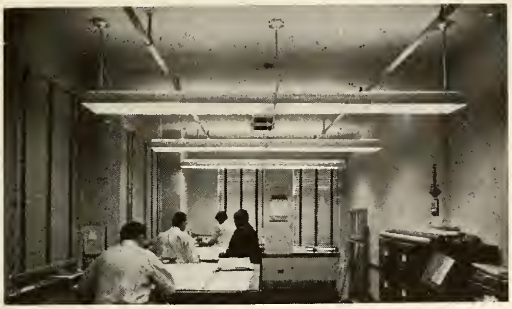


Above: 50 ft-c; L:$.08; E:$.32; C:$.11; A:$.26; T:$.77. Excellent lighting results can be obtained with equipment combining direct and indirect components. These units must be spaced closer together than those which are primarily indirect; however, rows may be 50-100 percent farther apart than with direct-lighting troffers. Shielding should be at least 35 degrees crosswise and 25 degrees lengthwise. Luminous sides help minimize ceiling brightness variations but usually dictate lengthwise viewing for comfort. Lengthwise shielding can be increased to at least 45 degrees with but moderate reductions in efficiency.

Below: 50 ft-c; L:$.06; E:$.27; C:$.10; A:$.43; T:$.86. Costs include installation of troffers but not the furred ceiling. Laid-in, co-ordinated ceiling systems may cost as little as 50-75 cents per square foot installed.

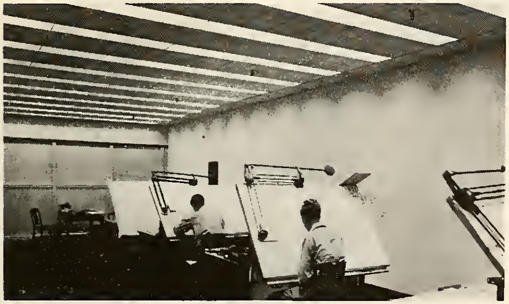


5. drafting rooms

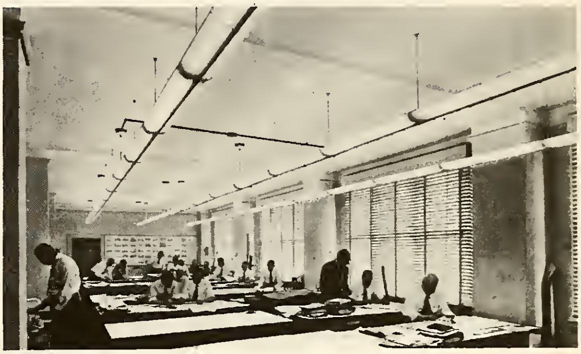


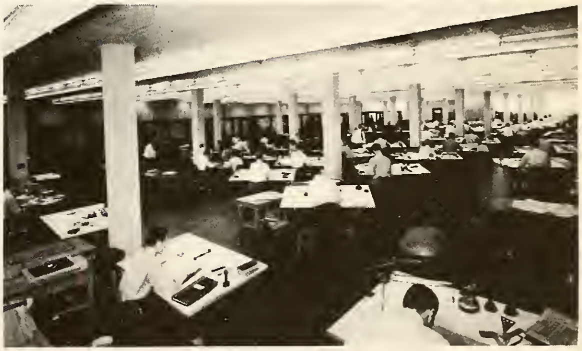
Above: general purpose lighting equipment, with enough indirect distribution to give some of the important quality characteristics desirable for drafting, may still produce shadows along straight edges parallel with the equipment. The sharp definition of the shadows is the source of difficulty, not necessarily the density. For a small office where tables can be properly located with respect to the lighting units, this system is a practical as well as an attractive solution.

Below: aluminum troffers in continuous rows offer top potentials for comfortable office lighting. In this system vertical drafting boards take full advantage of quantity and quality for seeing tasks by: 1) eliminating shadows; 2) providing freedom from reflection; 3) encouraging good posture; 4) increasing utilization of drafting room space.



Below: luminous indirect system. As there are no sharp shadows with this method it is well regarded by draftsmen.

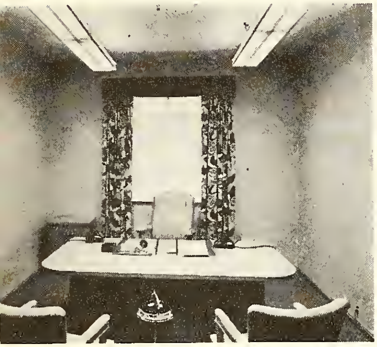




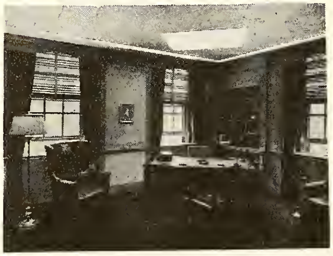
Above: office space with special lighting design for drafting is seldom available in rental space. By orienting the boards at 15-20 degrees to the axis of the rows of lighting equipment sharply defined shadows at major straight edge positions are avoided. Should the lighting be turned an orientation of 45 degrees is most practical; however, this technique imposes limitations of appearance, flexibility, and type of occupant.

6. private offices

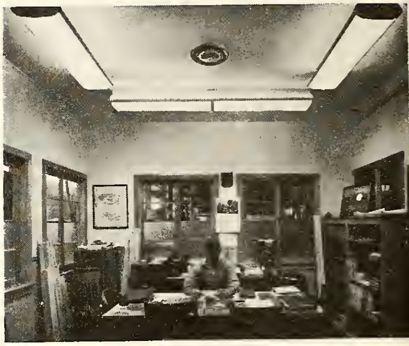
Below: lighting plus decoration can create the atmosphere for either individual or conference work in a private office. Venetian blinds and drapes at the window assist other visual comfort objectives. Simple,, suspended fluorescent fixtures, completely louvered, supply the general illumination.

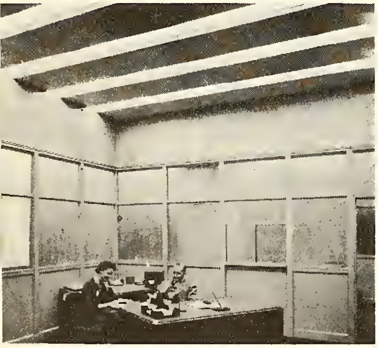


Below: in this view, custom furnishings are evident in the lighting. The element over the desk contains fluorescent sources in parabolic reflectors and is finished with a panel of low-diffusion plastic tiles. It is a tailored feature, exclusive for the indicated work position. A perimeter recessed element delivers a brightness to balance that of tasks on the desk.

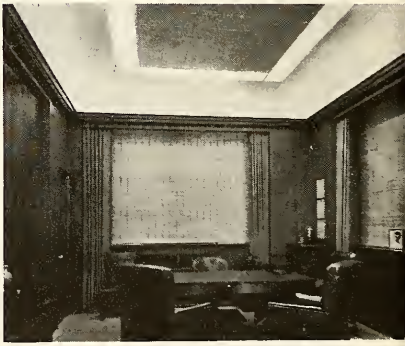


Below: L- and U-shaped lighting patterns provide light over the work space with little chance for direct or reflected glare. When these units are used alone it is essential that they have an indirect component to provide balanced brightness patterns throughout the remainder of the area. This approach restricts the placement of furniture and may be an inconvenient limitation if the occupant or a new occupant wishes a change in work location.





Above: the lighting and provisions of privacy for a plant executive need not depart from strict simplicity. Here, the acoustical ceiling accommodates the air conditioning unit and the rows of troffers. With an over-all pattern, furniture for this occupant may be located with complete freedom.



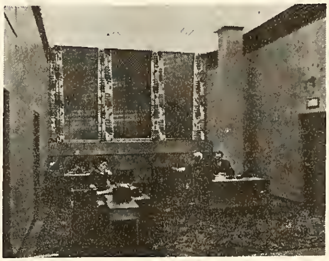
Above: indirect lighting from the perimeter cove supplements direct lighting from the recessed troffer pattern; this office was designed for a company officer or top executive.

7. corridors, lobbies, conference rooms

Below: corridor lighting is often slighted because it is merely circulation space. Since corridors often speak for a whole building in first and last impressions upon visitors, it is wise policy to light them carefully. Simple treatments, planned in co-ordination with the systems in adjoining areas, contribute safety plus respect and prestige for the property.

The character of the public space in an office building speaks for the reputation of the property and the tenants. In this example a single organization is the sole occupant of the building; the main floor lobby (left) is lighted by built-in features—luminous ceiling panel and recessed downlights. On an upper floor (above) a glass screen separates reception space from general offices.

Below: a continuous line of fluorescent lamps, mounted on wiring channel and shielded by a simple arrangement of louvers, provides efficient corridor lighting. This method supplies about 15-20 footcandles, meeting a trend to provide directly 20-50 percent of the illumination in circulation areas.



Above: louverall systems, most discussed of post-war techniques, may be employed for countless types of rooms. This installation, located in the loan department of a bank, has been carefully planned by the architect and lighting engineer to create luminous space. The design is unobtrusive yet it provides high level, comfortable lighting.

Below: in this small conference room the wedge-shaped table permits conferees and chairman to see each other directly. Each line of the general lighting equipment above the rows of chairs is fully shielded from the view of seated persons; this lighting provides 100-150 footcandles across the conference table. Projectors for motion pictures and slides may be operated conveniently at the narrow end of the table, as all lighting controls are duplicated there. The drapes back of the chairman's position may be drawn to expose a screen or a well-lighted presentation area.

Right: in this large conference room the pattern of the troffer system was suggested by the rectangular dimensions of the table and room. The work illumination on the table top can be brought to 70 footcandles. This system matches the simplicity of the light-colored walls and furnishings.

Lighting of Shops and Stores

BY R. T. DORSEY*

Alert merchandisers have long recognized that carefully planned lighting is a sound sales investment and surveys made by trade associations indicate that lighting is of top importance in modernization. Sales increases of 20 to 40 percent as a result of relighting are not unusual and installations in hundreds of new, successful stores over the past few years clearly establish planned lighting as a dynamic sales force. These advantages are not obtained by merely considering the type and number of fixtures to be installed. Successful store lighting is based on creating a selling environment and is closely integrated with the types of merchandise being sold, merchandising methods and arrangements, architectural control of space, and the design of interior finishes. Broadly speaking, three major considerations apply: (1) Directing *attention* to the store itself, to areas within the stores, and to specific items on display. Traffic control, impulse sales, and emphasis on high profit items can be regulated within wide limits. (2) Creating optimum conditions for the *appraisal* of merchandise. Lighting is a major factor in obtaining sales appeal. It is also important in stimulating the activities of customers and sales personnel, thereby improving turnover and increasing the unit of sale. A combination of fluorescent and incandescent sources is recommended for all selling areas. 96T12 slimline lamps generally offer the lowest over-all cost of light and have the advantages of higher efficiency, fewer lamps to replace, and long, smooth lines of light. (3) Contributing to the *atmosphere* desirable for a particular type of store—from the hustle and bustle of a supermarket to the subdued and sometimes dramatic environment of a fashion apparel shop.

To the owner of a shopping center, or a building that will contain shops and stores, the importance of lighting is paramount as it effects the success of his tenants, and thereby the income available from percentage leases. A major consideration of the owner and his architect, therefore, is to insure that adequate facilities are provided so that the tenant can utilize light to the best advantage and at the least expense.

interior considerations

In the early development of contemporary store lighting costly mistakes were sometimes made. Outlets installed on regular centers, regardless of space allotment or size of tenant, often led some tenants to install mediocre lighting on the outlets provided. Others wishing different layouts were forced to move outlets and wiring with the result that money would have been saved had outlets not been installed in the first place. Similar experiences were had with floor and wall outlets.

On many projects today, it is common practice for the owner in his initial planning to provide about 6-w capacity per sq ft for lighting. (Air conditioning load is added to this amount.) It is then desirable to rent all the space before construction begins so that the tenant can have his lighting and merchandising layout prepared in time to install outlets wherever needed and with a minimum of lost time and expense. An allowance can be made by the owner for a specified number of outlets, the difference to be paid by the tenant. Where space is not rented before the building is completed, service can be run to a panel board and the walls and ceiling left uncovered so that outlets can be installed subsequently.

These considerations are not limited to outlets. Such items as dropped ceiling sections and other architectural elements, whether necessitated by duct work or for design reasons, need the same preconstruction planning.

Window displays and the appearance of open-front shops from highway or sidewalk constitute another important facet of store lighting. For the store owner, well lighted windows mean valuable attraction power both day and night; for the individual shop there is a competitive advantage. This is readily apparent in some centers where individual shops are deliberately set up to compete with the department store. In every business area there is very real competition for the shopper's extra dollar—will it be spent in the supermarket, the millinery shop, the drug store, or the florist shop?

The problem of getting attention from the outside is particularly acute during the daytime (when the largest volume of traffic is passing by) as reflections in the window tend to obscure the interior. This is easily solved, but too often overlooked, by providing sufficient brightness on interior displays. Where window displays take up most of the front, high-intensity spot lights such as the new 300-w PAR 56 have proven to be one of the major advances in window lighting in the past several years. Where the window display as such is not important or does not exist, particular attention is needed on the walls or perimeter of the open-front store. Continuous lighted valances, lighted walls and showcases, spotlighted counter and wall displays, and bright niches or feature displays are of prime importance.

exterior considerations

Just as interior lighting affects sales in individual stores, exterior lighting offers many opportunities for furthering the success of a group of shops and stores. Sign lighting has received considerable attention both for daytime and nighttime effectiveness. Most architects will agree that

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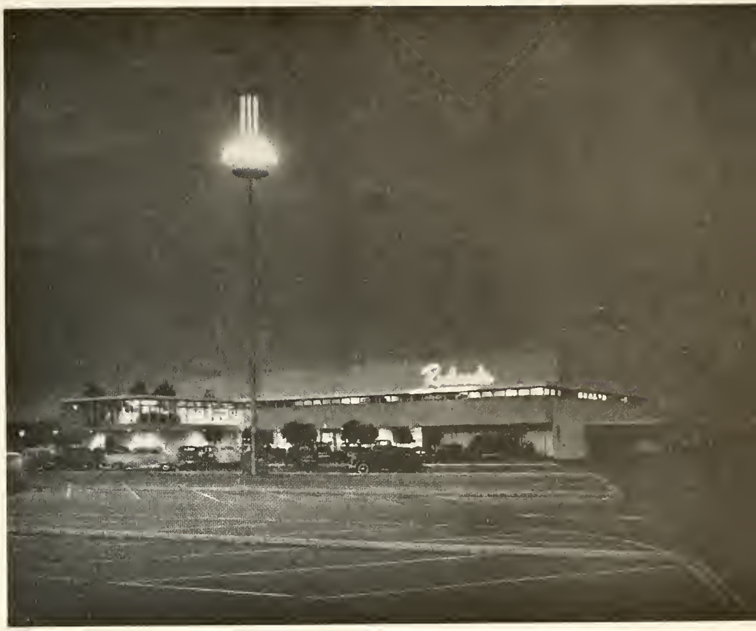
* *Store Lighting Specialist, Application Engineering Department, Lamp Division of General Electric Company.*

Figure 1—one ft-c of illumination, considered good practice for parking lots, can be obtained by floodlights of 1000- and 1500-w sizes on 60- to 80-ft poles; tall poles also provide mounting for attraction devices. Other ways of lighting parking areas include the use of mercury and fluorescent street lights.



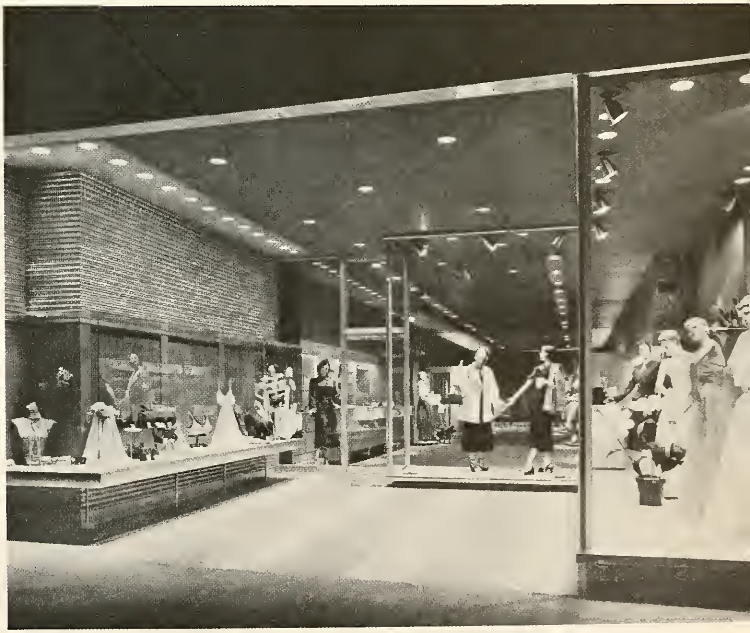


Figure 2—concentrated lighting at entrance and frontage builds up values on featured merchandise and guides the curious customer inside by day. Night use emphasizes the shop-front displays, utilizes interior system to lend depth and background interest. The interior walls, besides separating the shop from its neighbors, frame a display case in which the contents are made alive by calculated brightness distribution.

a certain degree of restraint imposed on sign design is highly desirable to obtain unified and dignified appearance. One widely accepted technique is to provide a continuous horizontal element of diffusing glass or plastic lighted from behind with continuous rows of $1\frac{1}{2}''$-diameter slimline fluorescent lamps. Rows are spaced 6″ apart and placed 6″ to 8″ behind the luminous panel for adequate brightness and uniformity. On this panel the tenant is at liberty to apply opaque or colored lettering of his own design. This treatment has the advantage of visually tying the structure together, and the large luminous area is an important factor in attracting the attention of passing motorists. It also tells the prospective shopper at a glance the range of types of stores in which he may shop.

Attention value, of a shopping center for example, is more important than some have realized. It has been found that a center not only obtains trade from the surrounding residential area, but a substantial amount is obtained from nearby towns. Thus, competition between shopping centers is of great importance.

Competitiveness involves among other factors identification at a distance, pleasing appearance, and maximum convenience for the ever-increasing practice of night shopping.

Identification at a distance can be accomplished by a prominent pylon. It is obviously desirable to have its message readily legible from the maximum distance at which it can be viewed. The following guide for determining letter size applies to signs when opaque letters appear against a luminous background. Letter height (ft) =

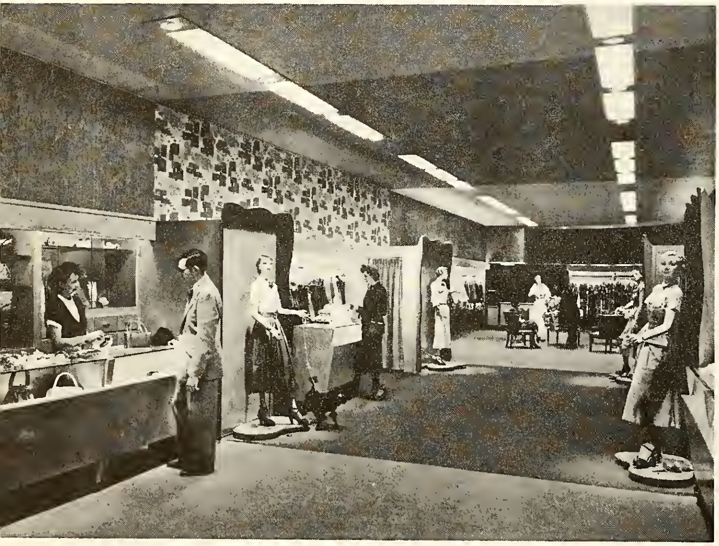
$$\frac{\text{Maximum viewing distance (ft).}}{300}$$

Where exposed lamps such as the 10-w S14 type in enameled colors are used to form the letter stroke, the guide becomes: Letter height (ft) =

$$\frac{\text{Maximum viewing distance (ft).}}{500}$$

Here another consideration is smoothness

The lighting installations in these shop areas (one pair for women, below; the other for men, below acrosspage) *indicate something of the range in which lighting can accommodate styling objectives. Each pair includes a shoe shop and an apparel department. In each instance the lighting has been co-ordinated with structure to enhance the merchandising with atmosphere and accents appropriate to the sales problems. In one pair, the ensemble of light and decoration aims to appeal to feminine customers; in the other, to make men feel at home.*



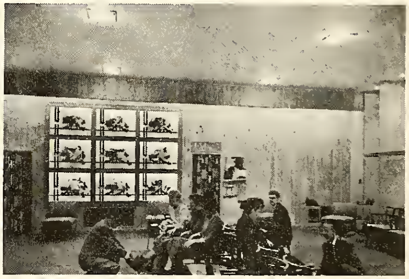


Figure 3—general lighting from incandescent downlights gives sparkle to shiny shoe surfaces, creates a warm atmosphere (above). *Eight-ft slimline lamps in standard cool-white provide color contrast on wall and niches. The pattern of brightness is stimulating as seen from the interior and helps attract attention outside the store.*

Figure 4—this long, narrow space (left) *is visually divided into selling areas by changing wall, ceiling, and floor treatments; by breaks in the rows of 3-lamps troffers; and by accents in brightness from PAR 38 spotlamps. Wall-case lighting directs attention to the display zone and contributes to a cheerful, stimulating atmosphere. Showcases at left are lighted by fluorescent "floodlights" instead of conventional glass-edge reflectors.*

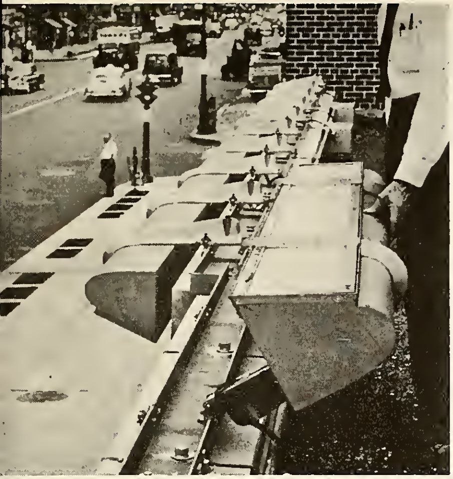
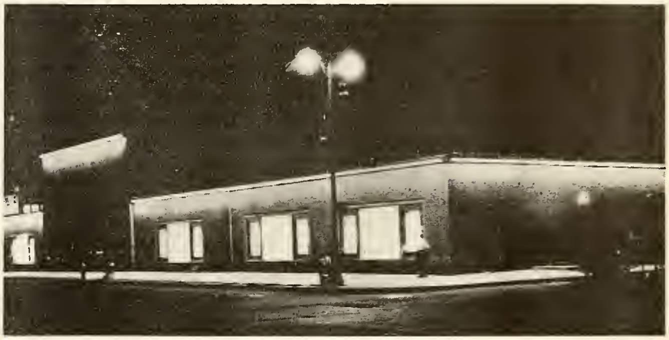


Figure 7—this sidewalk illumination provides protection and has advertising and floodlighting value; easy and safe maintenance are combined with durability and ruggedness. Units, mounted directly to the parapet (left), *rotate 180 degrees so that maintenance can be performed from the roof.*

Figure 8—high efficiency fluorescent lamps produce 10 ft-c on the sidewalk at night (below).

Photo: Rambusch Decorating Company, New York



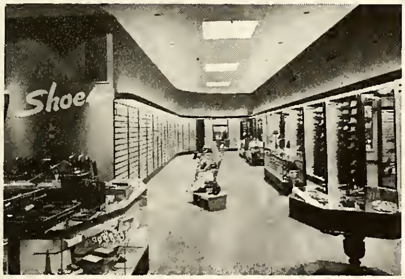


Figure 5—tailored effects achieved with standard lighting equipment give a trim, masculine touch to this lighting (above). *Continuous-valance lighting over the stock is provided with 40-w standard cool fluorescent lamps. Filament downlights are strategically located over the point of sale area. Recessed, louvered ceiling squares, equipped with 40-w fluorescent lamps provide a balancing component of diffuse illumination to accompany the downlighting.*

Figure 6—this pace-setting installation (right) *possesses: (1) logical arrangements of troffers in terms of proportions of the various areas, ceiling heights, and requirements for uniformity; (2) smooth appearance; (3) deluxe cool-white lamps for good appearance of people and merchandise; (4) spotlights combined with fluorescent; (5) quality perimeter and case lighting; (6) light-colored surfaces.*

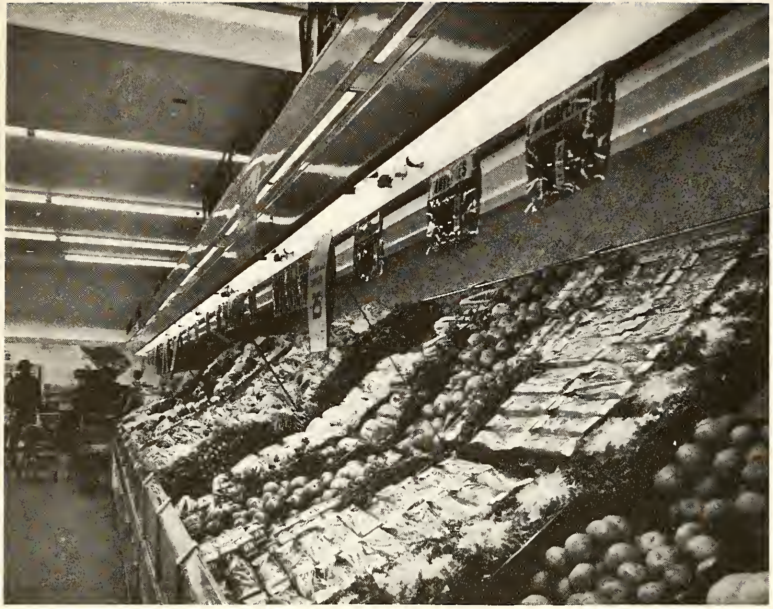


Figure 9—one of the most pronounced trends in supermarket lighting is the use of a valance around three of its walls. In this case, two rows of deluxe cool-white 30-w fluorescent lamps furnish 100 ft-c on the produce display. An additional row silhouettes the sign.

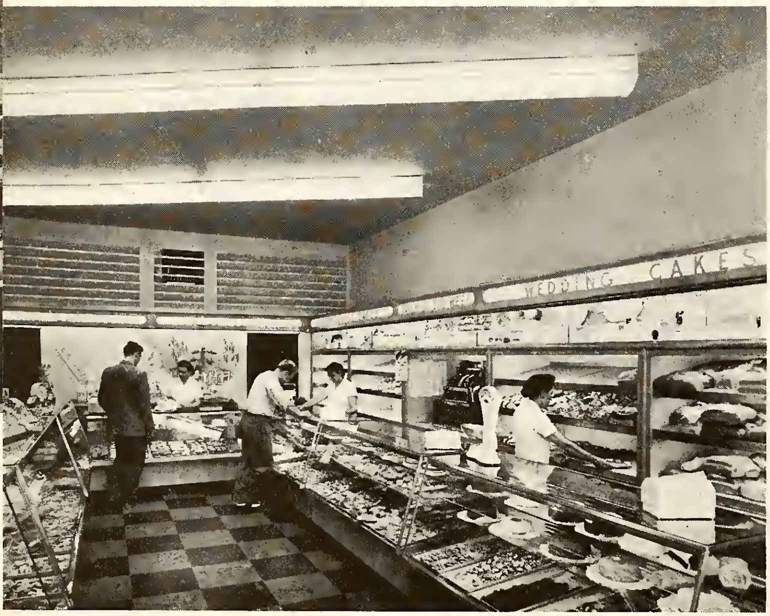


Figure 10—The high degree of integration in this bakery shop is more fully appreciated when considered in terms of lighting applied to zones. Thus, there is an overhead zone which includes the ceiling and upper walls; a display and selling zone which includes the wall and counter cases; and the traffic zone. The display zone is provided with twice the illumination value of the general lighting; each shelf is individually lighted.

of the letter stroke for close viewing. Spacing of lamps (ft) =

$$\frac{\text{Minimum viewing distance (ft).}}{1000}$$

To estimate the number of lamps required multiply $\frac{\text{Letter height}}{\text{Lamp spacing}}$ x Number of letters x 2.5. Plain block letters with a letter stroke width equal to 1/7 the letter height are the most legible. Where other letter styles are used, letter height must be increased to provide equal legibility.

Identification at a distance can be improved by employing bright elements atop floodlighting poles. Such a method, of course, is not sufficient in itself.

While attractive appearance in the daytime is almost entirely the result of the efforts of the architect and landscape designers, at night great opportunities are afforded by building floodlighting and landscape lighting. The cost of floodlighting the larger structures (typically the department store) is a very small percentage of the total investment, yet nighttime appearance is entirely dependent on it. The results of well-designed floodlighting have unquestionable advertising, institutional, and attention value.

The effectiveness of landscaping can be multiplied by lighting at night. While not yet widely used in shops and stores, the merits of such techniques have been clearly demonstrated in related fields.

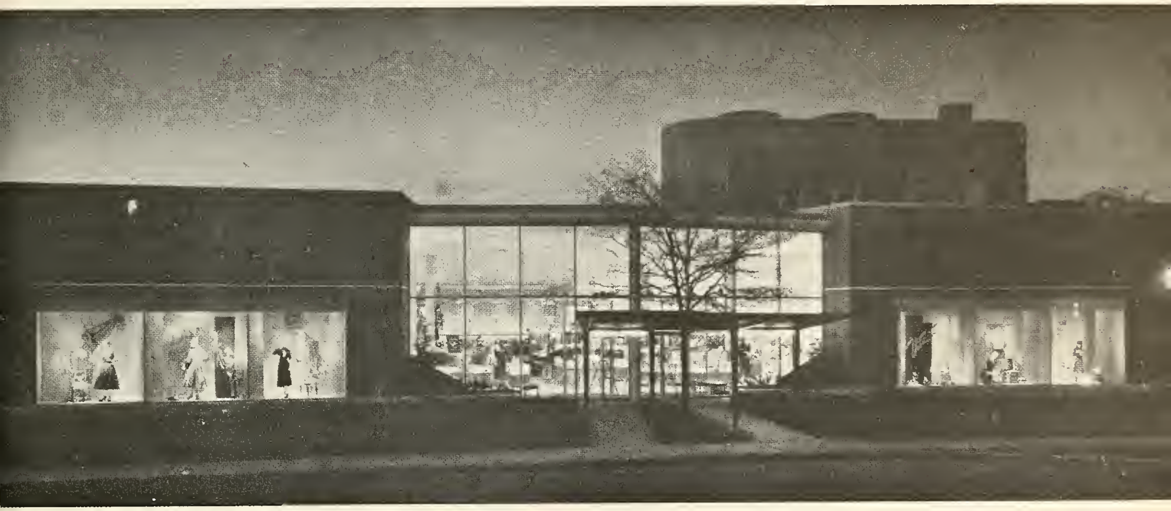


Figure 11—the night lighting of this suburban department store emphasizes three major considerations: (1) directs attention to the store itself; (2) creates optimum conditions for the appraisal of merchandise; (3) contributes to the atmosphere desirable for this type of store.
Photo: Julius Shulman

Maximum convenience and safety for shopping at night mean good lighting of the parking lot and walkways. Two standard practices have evolved for parking lots —high wattage floodlights on 60′ to 80′ poles, and street lights on 30′ to 35′ standards. One ft-c is considered minimum which requires about ⅛-w/sq ft for floodlights, about 1/25-w/sq ft for mercury or fluorescent street lights.

For floodlighting, enclosed types such as those used for major-league baseball fields are recommended. Good practice is to space poles not more than 5 times their mounting height. Thus 80′ poles would be spaced 400′ apart. On this basis 12 1500-w floodlights per pole would produce about 1 ft-c. An adequate maintenance program is important. Because of the cost of labor, cleaning every 400 burning hours with group replacement of lamps every 800 hours (no interior replacements) will give the lowest over-all cost of light in many cases. This is roughly biannual cleaning and annual group replacement of lamps.

From the appearance standpoint floodlights present a few somewhat spectacular tall poles as contrasted with many shorter street lighting standards. Less trenching is necessary for wiring floodlights and the tall poles offer an elevated position for marker lights.

Street lights, two per pole spaced 140′ apart, will produce about 1 ft-c with the H400-E1 Mercury lamp. When using the H400-J1 color-improved mercury lamps for better appearance of people, about 130′ spacing is needed for 1 ft-c. Mercury sources produce a distinctive color of light, but appearance of people is not nearly as good (even with the color-improved types) as with incandescent lamps.

Because of lower pole heights, street lights can be conveniently serviced from the ground by using disconnecting hangars, or from ladder trucks. A detailed economic study is necessary to determine whether group replacement or spot replacement of lamps is lower in cost. The rated life of mercury lamps at five burning hours per start is 4000 hours.

Fluorescent street lights with four 100-w rapid start lamps require about 40 percent more poles for the same illumination as mercury types using twin H400-E1 units. Actually, they are usually used to produce 2 to 5 ft-c. Closer spacing is used and excellent uniformity results. These fluorescent lamps offer about 6000-hours life, less glare, and good appearance of people. The several installations tried so far proved highly satisfactory.

Walkways, particularly around the mall between the typical avenues of shops, have offered some challenges to the lighting engineer, and some interesting solutions have been developed. Perhaps the most common is downlights recessed in the soffit of a projecting canopy.

Where the space between rows of shops is wide, decorative pylons can be developed to light the central area and to conceal spotlights used to light signs on the face of the canopy. Continuous strips of fluorescent lamps in the face of the canopy suitably shielded from principal traffic zones are another possibility.

LAMP RECOMMENDATIONS

R and PAR Lamps[1]

75 R 30

For close-range spotlighting of displays above wall cases and in niches and for downlighting in areas where relatively low levels of illumination are required.

300 R 40

For cove lighting, general lighting in show windows, and outdoor floodlighting. Available also in 150- and 500-w sizes, and in heat-resistant glass for outdoor use.

150 PAR 38

For medium-range spotlighting, downlighting in merchandising areas, and floodlighting and decorative lighting outdoors.

300 PAR 56

For high-intensity show window spotlighting, long-range spotlighting of displays, building and parking lot floodlighting, pylons, and decorative lighting.

Deluxe Fluorescent Lamps[2]

Deluxe cool white

Characteristics: (1) Keyed to natural daylight. (2) Mixes well with daylight; contrasts with incandescent. (3) Contributes to neutral, stimulating atmosphere. (4) Balanced effect on all colors of merchandise and room finishes.

Typical applications: mens wear, sports wear, sporting goods, white goods, hard goods, women's ready-to-wear, furs, toys, fresh produce, meats, flowers.

Deluxe warm white

Characteristics: (1) Keyed to incandescent. (2) Mixes well with incandescent; contrasts with daylight. (3) Contributes to warm atmosphere. (4) Emphasizes reds or oranges, yellows, with good appearance of greens and blues.

Typical applications: home furnishings, restaurants, evening wear, beauty salons, women's fashion clothes, baked goods, dairy products, rugs, furniture, shoes, luggage.

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[1] *These reflectorized lamps are increasingly popular in all lighting fields because they offer good control of light, convenience in use, sealed-in reflectors that cannot collect dirt, and because they can be concealed in small spaces.*

[2] *These are not fixed recommendations. There will be many instances when the opposite lamp will be preferred because of color scheme, other parts of the lighting system, merchandising methods, or personal preferences. Often, compromises are desirable in the interest of standardization of lamp types.*

Light—a Design Tool

BY J. W. HALL, JR.*

Technicians in each phase of a building program are prone to give their specialty item a sort of top priority in the function of a building problem. Thus, each of the design elements of a structure may become isolated and too little regard given to the whole. The mechanical functions of a building may be subdivided as: electric light and power, heating, air conditioning, mechanical ventilation, and plumbing. No one would would attempt to construct a present-day school without providing light and electric power; nor would he place children in a space for learning that was not properly heated. Health regulations insist upon suitable sanitary facilities and the standards for these have become higher and higher in recent years. Concurrently, lighting standards, which were at one time set at 5 foot-candles, have been raised to well over 25 foot-candles.

The time has long passed when an architect could design a convenient space arrangement, then tolerate "squeezing-in" electric wiring or heating facilities in a "catch as catch can" manner. As more and newer devices are made available for the improvement of our environmental circumstances, we in turn find more demands for the employment of these devices. The point has now been reached where mechanical functions in building are so important that the architect must consider them during *all* stages in the development of his structure. Because designers (and here we mean architectural designers) cannot be expected to have a working knowledge of all elements of mechanical design, a situation has developed which requires them to have certain specialists at hand. These men must have the mechanical knowledge and, at the same time, must give sympathetic understanding and appreciation to the architectural designer's ideas. They must bring to design an approach far removed from the strictly technical step-by-step or slide-rule solution which leads to the determination of a fixed quantity. Thus, a new type of mechanical specialist.

A man picks his clothes according to the occasion or the job at hand. So lighting a classroom must be considered according to its intended use and environmental impression. For this particular case study, we must first recognize the design conditions —the basic assumptions and compromises which are the foundation of all building design.

the design group

It is generally true that one major condition thrust upon the design is *cost*—the need for more space for less money. Further, there are conditions of climate, orientation, special site requirements, durability for low maintenance, flexibility for multiple use—and many others—that must be met. A designer or design team rolls out fresh, clean paper, reaches for pencils, and starts to give form to ideas that will fit together in a pattern fulfilling as nearly as possible the design requirements.

Because of their special gifts and skill, good designers are inherently dreamers and, in some instances, must be held in check by the laws of nature and the physical limitations of materials. Otherwise, the dream solution may take a form comparable to someone dressed in formal attire for a mountain-climbing expedition. In an attempt to give sun control, maximum ventilation, or protection against north winds, some architects have arranged structures which offer almost no space for the accommodation of mechanical features that are as basically necessary as substantial foundations and proper space arrangements.

The mechanical designer (with his new responsibility to the design unit) will, when necessary, find new uses for old devices, or create new devices for recognized needs. We must be prepared to question seriously any standard practices that seem unreasonable or not feasible during the study of new problems arising in the planning stage.

a specific problem

The lighting of the elementary school at Albany, Texas, is a case to illustrate the working of this design approach. In this instance, we were very fortunate in being able to work closely with the architects—Caudill, Rowlett, Scott & Associates—in all phases of their design work. Design conditions, in keeping with the general pattern, were dominated by the cost factor. Furthermore, climate conditions on the West Texas plains made it necessary to incorporate large sun- and brightness-control devices in order to maintain a reasonable brightness relationship between the daylight source and the working areas. If the architects were to follow their own design criteria by maintaining the balance of values in a trinity represented by *cost*, *education* and *environment*, the controlling elements would be *cost* and *environment*.

These controlling elements necessitated models of several sections for test purposes. The models showed that, for the Albany orientation, a clerestory-type, overhead light was most desirable under normal conditions of climate. However, the ordinary clerestory complicates the problem of the structural engineer and adds considerably to the cost of construction. At the same time, cost also indicated the use of readily-available, simple, standard materials. A solution was finally found in altering what is usually thought of as a typical section; i.e., a 12 ft wall height with light from one side. In this instance, the room width was increased, light introduced from both sides, and the out-of-scale 12 ft room height lowered to 7′-6″ by means of light control planes and louvers forming a room-wide clerestory. This low ceiling may be considered undesirable by some, but in the Albany School it adds very materially to the scale appropriate for small children.

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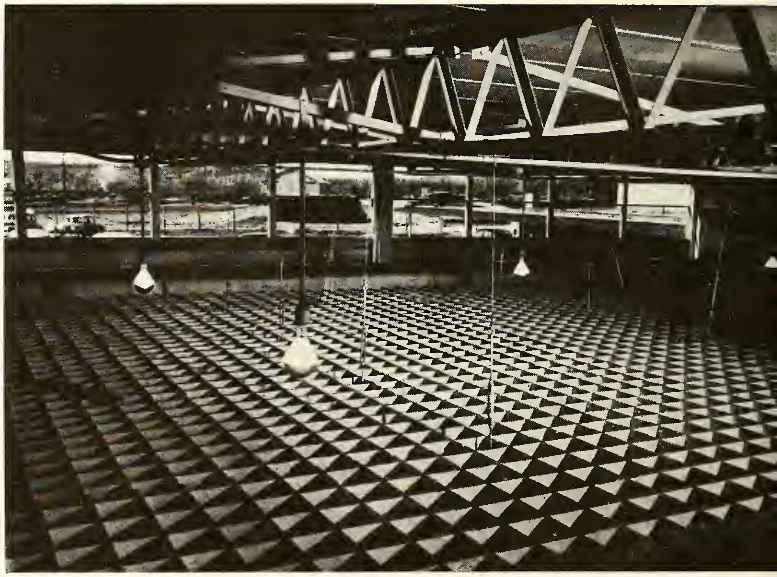
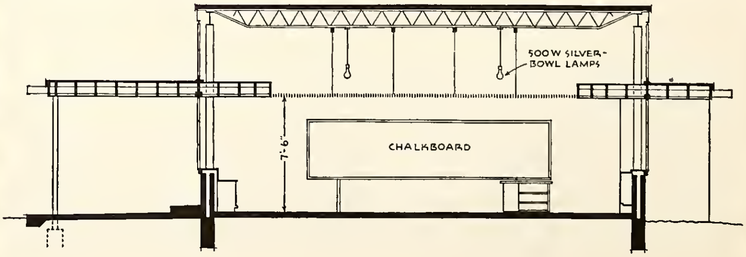
* *Consulting Engineer, Bryan, Tex.*

The sun control devices on the south serve the multiple purpose of providing a covered corridor and shade. The overhangs on the north act as sky controls by providing shade against the high brightness of the upper portions of the north sky. By painting the top of the sun control devices with a highly reflective finish, more light is thrown in a diffused pattern to the upper portion of the clerestory.

The room dimensions are 27 ft x 28 ft, and the space normally occupied within each room is approximately 20 ft wide; therefore, with an almost square room, there was a need to give the space apparent rectangular length. This was done by introducing light through a diffusing source which continues and connects the sun- and light-control planes (*see section*). Bids were taken on both wood and plastic eggcrate light-diffusing devices. The plastic material was much desired, but its excessive cost prohibited its use and a wood eggcrate, composed of 1 in. x 6 in. members 6 in. on center both ways, was finally installed. All of the space within the clere-



A highly reflective white paint was sprayed over the entire surface area of the clerestory and eggcrate louvers. The low ceiling, which required that luminaires be placed above the louvers (right), *gave the classroom an appropriate scale for small children* (below). *Natural light was introduced from both sides of the clerestory* (see section, below right).
Photos: Ulric Meisel



story and the eggcrate was sprayed thoroughly with a highly reflective white paint, for which the manufacturer claims 85 percent reflection.

All during the process of developing a typical section of the lighting scheme and testing the various qualities and quantities of each type of material, we were also responsible for providing space to accommodate mechanical functions. Our lighting problem and its solution progressed continously with the development of the section. (Heating mains and water pipes were run directly on the inner part of the deck created by sun-control devices.)

Since the ceiling itself is so low, it would have been impossible to introduce light at a reasonable cost by luminaires placed below or on the finished ceiling. Test sections proved that luminaires with built-in reflectors, placed high against the roof deck, would require 18 to 24 units for effective distribution over the eggcrate. Fluorescent lighting was considered, but rejected for two reasons: difficulty of changing tubes and the interference of roof framing with continuous-strip mounting. At this point during the design studies, it became necessary to decide what level of artificial illumination would be required. The test model showed that during cloudless and bright cloudy days, artificial illumination would be unnecessary as a uniform curve of 40 to 70 foot-candles obtained at the working level. Since the classrooms normally would not be used at night, 20 to 25 foot-candles at the working level were adequate. Test data indicated that this amount of artificial illumination on dark cloudy days would be adequate as supplementary light. For these reasons, incandescent silver-bowl lamps were chosen as luminaires. These lamps give a warm light that has reds and oranges in its normal application and acts as supplementary lighting on dark days when light from the skies tends to the blue end of the spectrum for a cold light. This incandescent-type illumination adds the necessary warmth for cheerful space environment.

variations from the norm

Calculations to determine the level of artificial illumination at night required certain broad assumptions, as well as taking liberties with standard practice. As indicated earlier, a design group must have a flexible and exploratory approach to the solution of problems brought about by integration of design.

The known, measurable quantities for determining artificial illumination included: lumen output of lamp—9400 for 500-watt silver-bowl lamp; reflection factor of clerestory space — approximately 85 percent; area of eggcrate over normally occupied space—540 sq ft.

Because the louvers were placed between the illumination source and the working level (source in this instance is assumed to be the underside of the finished roof or the top of the clerestory), they will have a light-passing capacity of 60 percent. We arrived at this 60 percent figure with simple test models and a completely diffused light source. Accepting an 85 percent reflection factor from the painted surfaces in the clerestory (with allowance for loss in reflection because of dust and deterioration), we found that six luminaires of 500 watts each, without reflector, if placed immediately above the eggcrate, would light the clerestory space sufficiently to distribute the desired amount of artificial light evenly to the working level—even on a pitch-black night.

a sort of summary

For those who will question our computation of desired light level, we should explain that the assumed light source, which is the reflecting area of the upper clerestory with many irregular surfaces, would not reflect the full 85 percent usable light, but approximately half the light received from the direct source.

Using the common formula for light level (where foot-candles equal total lumen output of light sources multiplied by factors of utilization and maintenance, then divided by area served), we get the computed level of 20 to 25 foot-candles. Measurements taken after the building was occupied prove our point, with levels of 21 to 26 foot-candles obtaining 30 in. above the finished floor.

This successfully completed installation is a result of the co-ordinated effort of various technical specialists, working together as an integrated design group. For this case, design conditions were recognized as guides to a successful culmination of the specific project. In addition to the success of the project and the satisfaction of educators and patrons involved, the entire design group found both esthetic and personal satisfaction in the job.

Classroom Lighting: Darien Junior High School

BY C. L. CROUCH*

The objective of all natural-lighting design is to utilize daylight so that it will produce (1) a level of illumination across and throughout the room that is as even as possible and (2) brightnesses throughout the field of view that are both comfortable and conducive to maximum visual performance. For years, architects and engineers have thought primarily in terms of providing daylight as efficiently and uniformly as possible through window proportions. Brightness relationships, when considered at all, were varied by the use of shades or blinds to cut out offending brightness areas (reducing quantity of light as well). Manually-controlled devices have not been satisfactory because the required constant readjustments are rarely made.

Practical experience and laboratory studies have now been united to demonstrate that designers must place equal emphasis on quality as well as quantity of illumination. Quality concerns the effect of lighting on the eyes—does it make one feel comfortable and does it make working seem easy? From laboratory studies it has been found that when extremes of brightness differences between various parts of the field of view are eliminated, there results a comfortable and efficient visual environment. As one looks from his task to the immediate surroundings, such as the desk, the eye maintains its good performance if it does not have to adapt to a brightness lower than one-third of the task. If the surroundings are more remote from the task, it has been reasoned that a greater departure in brightness relation can be permitted because it does not play as vital a role in efficient vision as the immediate conditions around the task.

Direct sunlight entering a room produces brightnesses far out of proportion to those in other parts of the room and results in discomfort, glare, and inefficient vision due to extreme changes to which the eye must adapt. Even on overcast days, the sky is far brighter than any area within a building and large areas of sky in the field of view may be uncomfortable. It is always necessary, therefore, to equip the fenestration with some type of shielding medium to minimize direct sunlight entering the room. Recommended brightness ratios have been set forth in the "American Standard Practice for School Lighting" as shown *(Table I)*. In order to achieve these conditions, all light sources, both daylighting and electric, must be adequately shielded, the illumination must be well distributed, and the reflectances of desks, floors, walls, chalkboards, and ceilings should be related and kept within prescribed limits *(Table III)*.

In the design of the fenestration for the Junior High School, for Darien, Connecticut, the architects' aim in light control was not only to eliminate direct sunlight on the task, but also to reduce sky glare. For uniformity of lighting, bilateral fenestration was considered mandatory. Louvers, installed on both exposures (exterior walls of classroom and corridor face east and west respectively), eliminate direct sunlight and reduce the average brightness of the glass areas as seen from the interior. The eyes adapt to the average of the louver brightness and the brightness of the sky visible between the louvers. Angle tilt and spacing of the 3″ fixed louvers (30 degrees from horizontal and 2-½″ apart) render exterior objects visible to the occupants. Light from the corridor side enters the classroom almost completely by reflection from the corridor floor *(Figure 2)*.

The original design provided louvers approximately 2′ away from the outside sur-

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* *Technical Director, Illuminating Engineering Society.*

Table I—Recommendations for Limits of Brightness Ratios[1]

	Ratio
a. Between the seeing task and immediately adjacent surfaces, such as between task and desk top, with the task the brighter surface[2]	1 to ⅓
b. Between the task and the more remote darker surfaces in the surrounding visual field, such as between task and floor	1 to ¹⁄₁₀
c. Between the task and the more remote brighter surfaces in the surrounding visual field, such as between task and ceiling	1 to 10
d. Between luminaires or windows and surfaces adjacent to them in the visual fields	20 to 1

[1] "American Standard Practice for School Lighting"

[2] Chalkboard and some art and shop tasks are illustrations of cases where the reverse ratio of 1 to 3 may apply.

Table II—Brightness Ratios: Darien Junior High School

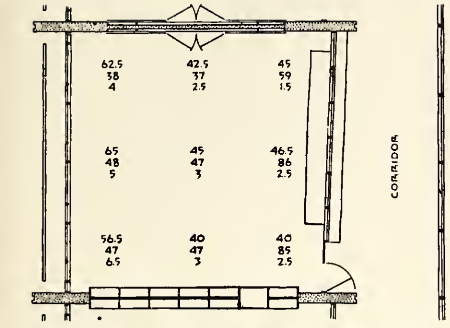
	Sunny day	Overcast day
a. Between white paper and desk top	1 to ¾	1 to ½
Between chalkboard and adjacent tackboard	1 to 2	1 to 2
b. Between paper on desk and floor	1 to ½	
Between chalkboard and brick wall	1 to 1	1 to 1
c. Between paper on desk and average of louver and sky brightness	1 to 35	1 to 25
Between chalkboard and corridor ceiling	1 to 10	
d. Between clear sky seen between louvers and louvers	14 to 1	6 to 1

Table III—Reflectances[1]

	American Standard Practice Recommendation	Darien Junior High School
Ceiling	80-85	75-80
Floor	15-30	40
Wall	50-60	
brick		20
tackboard		70
Desk tops	35-50	45

[1] Percentages

Architects: Ketchum, Gina & Sharp.



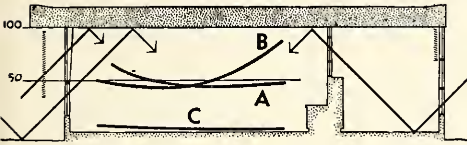


Figure 1—illumination values in footcandles (above, top). *Upper numbers indicate value predicted from study of model; center figures show measurement with sun on corridor fenestration; bottom quantities are for dark, overcast day.*

Figure 2—illumination distribution across center of room (above). A—*predicted from model for uniform sky (1000 ft-L);* B—*measurement with sun on corridor fenestration;* C—*dark day (500 ft-L).*

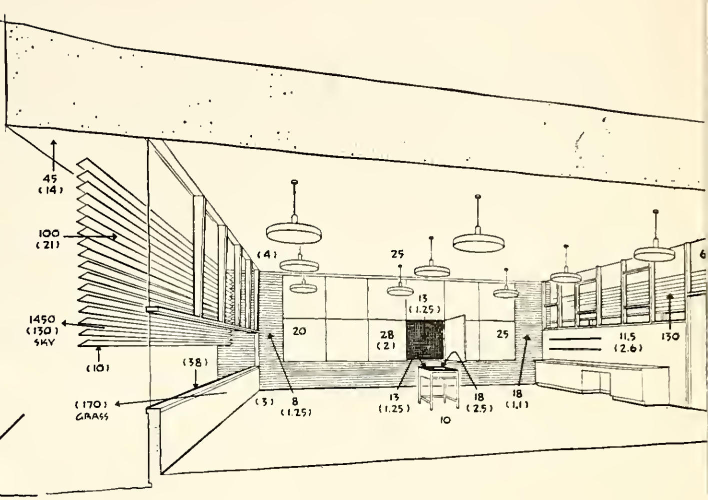


Figure 3—brightness distribution on sunny day (4500 horizontal ft-c in sunlight, 560 ft-L overhead, 2100 ft-L at east horizon) with direct sunlight (5700 vertical ft-c) on corridor fenestration. Values for dark, overcast day (500 ft-L uniform sky) are indicated in parentheses.

face of the exterior classroom wall and on the corridor side of the glass between the classroom and the corridor *(photo, page 91)*. Later experimentation, however, has shown advantages in moving the latter set of louvers to the inside of the exterior corridor wall: less change in eye adaptation when entering the classroom from the corridor, greater feeling of space within the classroom, and cooler corridors. All of the following observations are for a classroom with this new arrangement.

The brightness distribution with the bilateral fenestration is shown for both a bright and dark day, as well as the excellent quality of the resultant interior brightness distribution *(Figure 3 and Table II)*. Interior reflectances measured at Darien and those recommended in the "American Standard Practice for School Lighting" are also compared *(Table III)*. From an illumination standpoint, the brick masonry is much darker than is usually considered desirable for walls. Since much of the brick area is adjacent to the window, however, under daylight conditions the brightness distribution is still within the limits recommended *(Table I)*. In addition, most of the wall surface within the field of view is covered with tackboards.

In the preliminary planning of this structure, the architects submitted several designs to W. W. Caudill, Bob Reed, and E. E. Vezey of the Texas Engineering Experiment Station for testing under a simulated diffusing sky. Without sunlight and assuming a 1000-ft-lambert sky, the researchers predicted the values shown *(Figures 1 and 2)* for the design finally selected. Values measured in the finished classroom under a uniform sky (approximately 500-ft lamberts) and on a bright day with sunlight falling on one side are also presented *(Figures 1 and 2)*. The distributions do not agree exactly, due to the sunlight, different ground reflections, and the use by Caudill and his associates of a different interior reflectance pattern and a different reflectance of louvers.

These illustrations show that with sunny conditions, the illumination is adequate.[1] On a heavily overcast day, the daylighting is very inadequate—a condition, however, that is true with any kind of fenestration. (Suitable high-quality electric lighting is necessary to provide the lighting on dark days in all structures.) Note the excellent uniformity of illumination throughout the room as compared to the nonuniformity from window to opposite wall for commonly used fenestration. This uniformity, in conjunciton with the favorable brightness ratios that exist *(Table II)*, demonstrate the effectiveness of this design.

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[1] *The "American Standard Practice for School Lighting" recommends 30 footcandles for regular classrooms.*

Fluorescent Lighting: What Frequency Is Most Suitable?

BY DOMINA EBERLE SPENCER*

The architect accepts without question the customary 60-cycle operation of lighting circuits, as nearly all of our electric energy is generated at 50 or 60 cycles per second. The architect takes the available frequency and expects the engineer to manage the details of distributing the standard frequency to all electrical devices used in his buildings. The purpose of this paper is to question the acceptance of the standard 60 cycles per second in the lighting of buildings with fluorescent lamps.

At the turn of the century, when a-c generating stations were becoming well established, there were two principal applications: motors and incandescent lamps. The only reason why a frequency as high as 60 was chosen was to eliminate flicker in Edison's incandescent lamps. Today, however, higher frequencies are widely used: airplane equipment is ordinarily designed for 600 cycles per second to reduce weight; standard frequencies for induction heating of metals are 1000, 3000, and 10,000 cycles per second.

A study of the properties of fluorescent lamps shows that they are entirely unsuited for the 60-cycle operation. To perform at their best, fluorescent lamps should be operated at a frequency at least *50* times as high. In this paper circuits for these higher frequencies will be described and costs analyzed; it will be shown that many advantages result from operating fluorescent lamps at their most suitable frequency. In addition, economic savings result and the weight of metal required for the auxiliary equipment can be markedly reduced.

The architect should seriously consider the possibility of changing to a higher frequency whenever he is planning fluorescent lighting for a large building, or for an installation in a d-c district, or for a project with an independent generating station.

the best frequency

The choice of the best frequency for fluorescent lighting installations is based on the consideration of a number of factors. The most important of these is the volt-ampere characteristic of the lamps.

Incandescent Lamps

The characteristics of an incandescent lamp depend on the temperature of its filament.[1] As the temperature varies during a cycle of the applied voltage, the resistance of the lamp also varies and the volt-ampere curve has the shape shown (*Figure 1-A*). If the frequency is low, there is time for the filament to cool appreciably during a half-cycle and the loop is pronounced. As the frequency is increased, the temperature of the filament becomes nearly constant. Dynamic thermal equilibrium is established and the volt-ampere characteristic becomes essentially linear. These conditions are satisfactorily approximated for an incandescent lamp at 60 hertz[2] (*Figure 1-B*). At this frequency, the temperature of the incandescent filament is nearly constant, dynamic thermal equilibrium is established, and flicker is not perceptible.

Fluorescent Lamps

The characteristics of a fluorescent lamp depend on the state of ionization of the vapor within the tube.[1] Deionization of the vapor in a fluorescent lamp is very rapid compared to the cooling of an incandescent filament. At 60 hertz, the volt-ampere characteristic of a fluorescent lamp is a complicated affair (*Figure 2-A*). To establish dynamic equilibrium for the state of ionization in the fluorescent tube, we must increase the frequency until there is not time for deionization during a half-cycle of the applied voltage. At such frequencies, the volt-ampere characteristic of the fluorescent lamp becomes linear. For the fluorescent lamp, this occurs not at 60 hertz but at approximately 3000 (*Figure 2-B*). Therefore, fluorescent lamps will operate at their best only if the frequency is raised above the standard by a factor of at least 50.

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* Associate Professor of Mathematics, University of Connecticut, Storrs, Connecticut

[1] *V. J. Francis,* Fundamentals of Discharge Tube Circuits, *John Wiley and Sons, New York, N. Y., (1948)*

[2] *The "hertz" is the meter-kilogram second unit of frequency. 1 hertz = 1 cycle per second*

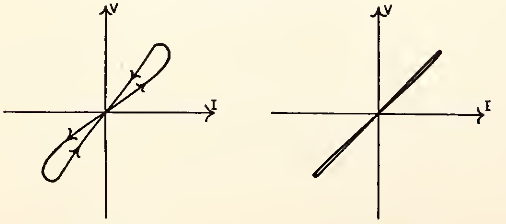


Figure 1—incandescent lamp

(A) 25 HERTZ

(B) 60 HERTZ

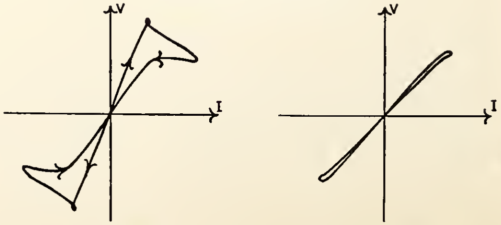


Figure 2—fluorescent lamp

(A) 60 HERTZ

(B) 3000 HERTZ

More Lumens Per Watt

As dynamic equilibrium is approximated, the amount of light radiated (lumen) for each watt input is increased (*Figure 3 and Table I show the type of change that results*). The higher the frequency, the more light we obtain for the same power input. The increase continues up to about 10,000 hertz. The data[3] of Campbell, Schultz, and Kershaw (*Table I*) indicate that increases of as much as 13% occur at 10,000 hertz. Data[4] taken with a different circuit gave a somewhat greater increase of 15% for 40-w T-17 lamps operated at 3000 hertz.

Long Lamp Life

The life of a fluorescent lamp is cut short as a result of ion bombardment of the filament during starting and during steady state operation. If dynamic equilibrium is attained and quick starting is provided, the life of the fluorescent lamp will be increased. Accelerated life tests[4] made on 40-w T-17 lamps at 3000 hertz showed an increase of 12% in lamp life as compared to 60-cycle operation on G.E. 89G400 ballasts. It is felt that the 12% increase obtained with the first life tests is on the conservative side. Results in a test installation in the U. S. Agriculture Department seem to indicate that the life at high frequencies is practically indefinite.

Radio-Frequency Interference

Will a fluorescent lighting system operated at 3000 hertz interfere with radio reception? The answer is no. Radio-frequency interference sometimes encountered with fluorescent lamps has nothing to do with the frequency at which the lamps are operated (so long as they are not operated in the broadcast band). It depends, rather, on the wave form.[5] If a linear volt-ampere characteristic is obtained (*Figure 2-B*), the voltage and current waves are pure since waves and radio-frequency interference is completely eliminated. With a poor wave form (*Figure 2-A*), the spectrum is rich in high-frequency overtones which may produce radio-frequency interference.

Flicker

Above 63 hertz, Hecht and Shlaer[6] have shown that the eye perceives no flicker. Thus, any increase in the frequency at which fluorescent lamps are operated will completely eliminate flicker.

Stroboscopic Effect

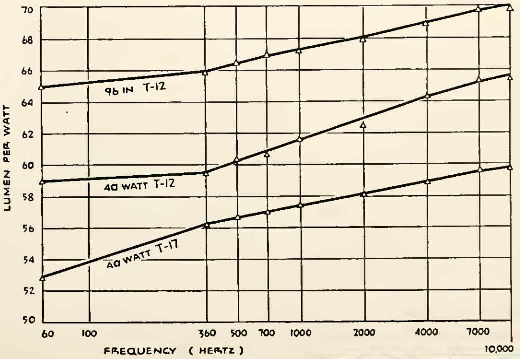
Stroboscopic effect is an entirely different thing. A light source operated at such a high frequency that no flicker can be detected may thoroughly confuse our observation of moving bodies. Rotating machinery may appear to stand still when it is moving, to go forwards when it is actually going backwards, or to rotate at an entirely deceptive speed. Difficulty with stroboscopic effect is not experienced for 60-cycle incandescent lamps, which flicker[7] less than 12%. With fluorescent lamps, on the other hand, stroboscopic effect may be very troublesome. Slow-decay phosphors are now being used which reduce[7] the 60-cycle flicker from 100% to between 27% and 58%. This may still cause trouble at 60 hertz but is negligible at the lowest frequency that has been considered[8] for "high-frequency" operation of fluorescent lamps (360 hertz).

Table I

Lumen Output of Fluorescent Lamps as a Function of Frequency
(At rated power input)[3]
Lumens per watt expressed as percentage of
60-hertz values

Frequency (hertz)	40-watt T-12	40-watt T-17	96-in. T-12
60	100%	100%	100%
360	101%	107%	102%
1000	104%	109%	103%
3000	108%	110%	106%
10,000	111%	113%	108%

Figure 3—lumen per watt as a function of frequency[3]



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[3] *Adapted from Figure 1 in J. H. Campbell, H. E. Schultz, and D. D. Kershaw, "Characteristics and Applications of High-Frequency Fluorescent Lighting," Paper #16, National Technical Conference of the Illuminating Engineering Society, Sept. 8-12, 1952, Chicago, Ill.*

[4] *Measurements made in collaboration with R. A. Coradeschi who has recently joined the staff of Bell Telephone Laboratories, New York, N. Y.*

[5] *J. Warren Culp: "Noise in Gaseous Discharge Lamps,"* Illuminating Engineering, *Vol. XLVII, 1952, pp. 37-46*

[6] *S. Hecht and S. Shlaer, "Intermittent Stimulation by Light," V: "The Relation Between Intensity and Critical Frequency for Different Parts of the Spectrum,"* Journal of General Physiology, *Vol. XIX, 1936, p. 965*

[7] *Arthur A. Eastman and John H. Campbell, "Stroboscopic and Flicker Effects From Fluorescent Lamps,"* Illuminating Engineering, *Vol. XLVII, 1952, p. 27*

[8] *J. H. Campbell, "High Frequency Operation of Fluorescent Lamps,"* Illuminating Engineering, *Vol. XLIII, 1948, p. 125; J. H. Campbell and B. D. Bedford, "Fluorescent Lamp Operation at Frequencies Above 60 Cycles,"* Proc. Nat. Electronics Conference, *Vol. III, 1947, p. 307; Kuo-Shu Chao, "Investigation of Fluorescent Lamps at Frequencies Above 60 Cycles," S. M. Thesis, Electrical Engineering, M.I.T., 1949; John A. Losh, "Fluctuations in Color and Helios of a Fluorescent Lamp," S. B. Thesis, General Engineering, M.I.T., January, 1950*

Acoustic Considerations

The hum from 60-cycle ballasts is produced by vibration of magnetic-core laminations. The sound is radiated at a frequency of 120 hertz.

High-frequency circuits contain a smaller number of noisy inductors than 60-cycle circuits. Nevertheless, it is desirable to make sure that any sound radiated from the auxiliary equipment will cause as little annoyance as possible. According to Knudsen and Harris,[9] minimum masking effect will occur if the frequency is near the top of the audible spectrum. The frequency range for ordinary speech is between 100 and 7000 hertz, while the ear is most sensitive in the vicinity of 3000 hertz. A 60-cycle circuit gives noise at 120 hertz and is particularly effective in masking the entire range of frequencies used in speech. If a 1500-cycle circuit is employed, the ear will be extremely sensitive to even a small amount of the 3000-cycle noise. But if the frequency of the generator is 3000 hertz, the noise occurs at 7000 hertz, near the top of the audible region. Such noise produces little masking effect and the ear is relatively insensitive to the noise itself. On an acoustic basis, 3000 hertz can be considered as the minimum acceptable frequency.

Higher frequencies will be entirely inaudible to human occupants.

Weight of Auxiliary

On the basis of engineering design of the necessary capacitors and reactors, the highest possible frequency is best. The size of the auxiliary decreases rapidly as the frequency is increased. The higher the frequency, the smaller and lighter the auxiliary equipment.

Transmission

The only factor that tends to limit the use of high frequencies is the distance to which an uncompensated transmission line can be extended without encountering large fluctuations in the line voltage when the load is changed. This distance is generally taken as a quarter wavelength. Thus for 60 hertz we can anticipate possible trouble at about 778 miles, for 1000 hertz at 47 miles, for 3000 hertz at 16 miles, and for 10,000 hertz at 5 miles. As the buildings or plants likely to be considered for high-frequency systems in the near future are not likely to be 5 miles across, we need anticipate no immediate difficulty on this score. If public generating plants at high frequency were to be constructed, these voltage fluctuations would be eliminated by using compensated transmission lines.

The Frequency to Choose

All of the characteristics of the lamp indicate that a frequency of at least 3000 hertz should be used. Acoustical and weight considerations indicate that even higher frequencies would be advantageous. Transmission-line characteristics, on the other hand, give some advantage to lower frequencies. Thus, we can conclude that *the lowest frequency suitable for operating fluorescent lamps is 3000 hertz.*

The possibility of choosing 6000 or 10,000 hertz should not be entirely discarded. Frequencies higher than 10,000 hertz need not be considered for fluorescent lighting because: (1) the improvement in fluorescent lamp characteristics beyond 10,000 hertz is negligible; (2) motor-generators for frequencies beyond 10,000 hertz are not available.

circuits

The simplest circuit suitable for high-frequency operation will be described here. Circuits are discussed in greater detail in another paper.[10] In most cases encountered by the architect today, power must be obtained from 60-cycle lines. A motor-generator set is used to obtain the desired

Table II—Design Data for Group Operation Circuit

	Type of lamp		
	40-watt T-12	40-watt T-17	96-in. T-12
Rated lamp current (amp)	0.430	0.425	0.425
Rated lamp voltage	99	103	190
Equivalent lamp resistance (ohm)	230	242	447
Recommended minimum starting voltage	385	385	625
C (microfarad) at 3000 hertz	0.0611	0.0607	0.0379
L (henry) at 3000 hertz	1.972×10^{-3}	2.00×10^{-3}	5.84×10^{-3}

Operating 25 40-w lamps, or 14 96-in. lamps from a single switch

Figure 4—A, B, C to Z represent groups of lamps each controlled by a single switch and connected as shown in Figure 5.

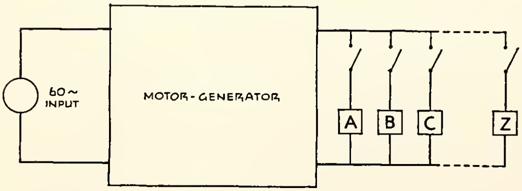
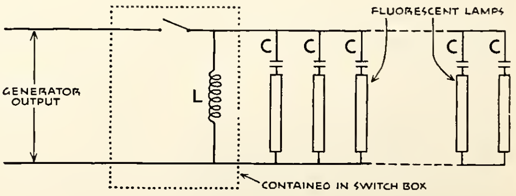


Figure 5—group operation circuit



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[9] V. O. Knudsen and C. M. Harris, Acoustical Designing in Architecture, John Wiley and Sons, New York, N. Y. (1950)

[10] D. E. Spencer, "Frequency and Fluorescent Lamps," to be published

frequency (*Figure* 4), and the Group Operation Principle is employed. The auxiliary equipment is not designed as a one- or two-lamp ballast, as generally used today, but is arranged for the entire group controlled by a single wall switch. Much of the auxiliary can then be enclosed in an acoustically-treated wall switchbox.

In d-c districts, fluorescent lamp operation is not, in any case, economical without a motor-generator set. The frequency of the motor-generator required should not be 60 but 3000 or perhaps 10,000 hertz. If a large factory or office building is to be supplied by its own generating system, the generator should be built for a frequency suitable for fluorescent lamps.

The simplest group-operation system that has been tested[11] is shown (*Figure 5*). The line voltage is sufficient to start the lamps. The capacitors limit the current to rated value, while the inductor L provides unity power factor at each switch. Design data for three types of fluorescent lamps is shown (*Table II*). A small capacitor of roughly 0.05 microfarad is required in series with each lamp, while a few millihenries inductance concealed in the switchbox provides power factor correction for a large group of lamps.

If there is objection to using as high a line voltage as is required to start the lamps, low-line voltage can be obtained by using a more complicated set of coils in the switchbox and larger capacitors in series with each lamp. Such a circuit is described in detail in another paper.[10]

cost

The architect who wishes to employ high-frequency lighting in a proposed building must, of course, convince his client that this is not a wild scheme to waste money. He must demonstrate, if possible, that the new system is not only advantageous in the respects previously mentioned but also that it provides an economic saving.

To show that this can be done, let us consider the design of an actual building. The 40-w T-12 lamp is the most economical[11] and will be used in this design. Costs of a similar system using the 96-in. T-12 lamp are only a few percent higher; but costs of a similar system using the "low-brightness" T-17 lamp are approximately 50% more. Thus, on an economic basis, the use of T-17 lamps is never justified. It is always more economical to use the 40-w T-12 or the 96-in. T-12 lamp with a quality lighting fixture.

An office building is to be lighted by a 3000-hertz system using the output from a 200-kva three-phase motor-generator installed in the basement. Wall outlets for motors, computing machines, fans, and electric typewriters are to be on an independent 60-cycle circuit.

The power delivered to each lamp is 39 w, the power to the inductor L per lamp is 1.25 w, giving a total of 40.25 w per lamp. The 200-kva generator can therefore supply power to operate 4970 lamps. Losses in the motor-generator may be taken at 19%. Therefore, the power taken from the 60-cycle line at rated load is 238 kw. The lumen output of each lamp is 2540 lumen, and the total lumens for the entire building is 1.264 x 10^7 lumen.

Take the cost of luminaire (without ballast) at $6.86 per lamp and the combined cost of capacitor and inductor (per lamp) as 95¢. Thus, the luminaires cost $7.81 per lamp, or a total of $38,800 for the high-frequency system. Assuming a cost of $25 per kva for the motor-generator, its initial cost is $5000. Or the *total initial investment exclusive of lamps is $43,800.*

If lamp life is assumed to be increased 12% above normal value, lamps will last 2800 hours. Assuming normal discounts, lamps are purchased at 92¢ apiece. If lamps are burned 2500 hours per year, *annual lamp replacement will cost $4090.* At 1.5¢ per kwh *energy costs each year are $8910.*

If the fixed charges per year are 10% of the investment, the annual cost will be:

Fixed charges	$4380
Lamp replacement	4090
Energy	8910
Total annual lighting cost with 3000-hertz system	$17,380

At 60 hertz the cost of the same luminaires with standard G.E. instant-start ballasts is $10.00 per lamp. But the output of the lamps is only 2350 lumen, so 5380 lamps must be used to provide the same quantity of light. The *initial investment in luminaires and ballasts is $53,800.*

At a lamp life of 2500 hours, *annual lamp replacements will cost $4950.* Power required per lamp is 39 w for the lamp and 11 w for the ballast or a total of 50 w per lamp. The *total power for the 60-cycle system is 269 kw. Annual energy cost is $10,460.*

If fixed charges are again taken as 10% of the investment, the annual cost will be:

Fixed charges	$5380
Lamp replacement	4950
Energy	10,460
Total annual lighting cost with 60-hertz system	$20,790

Thus, the architect's client may expect to save $3410 each year by installing the high-frequency system, a saving of 16% of the annual cost of the 60-hertz system.

A comparison of the weight of the auxiliary required is also of interest. The weight of the 3000-cycle auxiliary (including the motor-generator set at 2.28 lb per lamp) is 2.41 lb per lamp or a total of 12,000 lb for the building. On the other hand, a standard 60-cycle instant-start ballast weighs 4.13 lb per lamp, and the total weight required for the entire building is 22,200 lb. The weight of metals required for the new system is only 54% of that ordinarily used.

The client is justified in choosing the high-frequency system for his new office building. He likes the trim appearance of the luminaires which look as though they contain no ballasts. He is glad to be rid of stroboscopic effect, ballast hum, and radio-interference. He recognizes that longer life means less money spent on lamp replacement and less work for his janitors. He has just been reading a summary of the President's Materials Policy Report[12] and has a warm patriotic glow as he realizes that he can save over 6 tons of steel and copper by choosing the new lighting system. And finally, when he sees that he can save over $30,000 in 10 years, three-fourths of his initial investment, he is completely sold. Ground will be broken in the spring. A revolutionary idea in fluorescent lighting is about to leave the laboratory and drawing board and become accepted practice.

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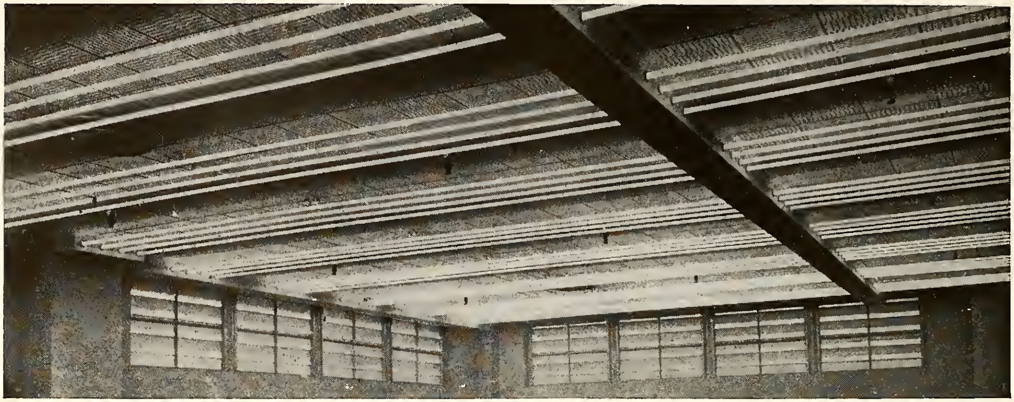
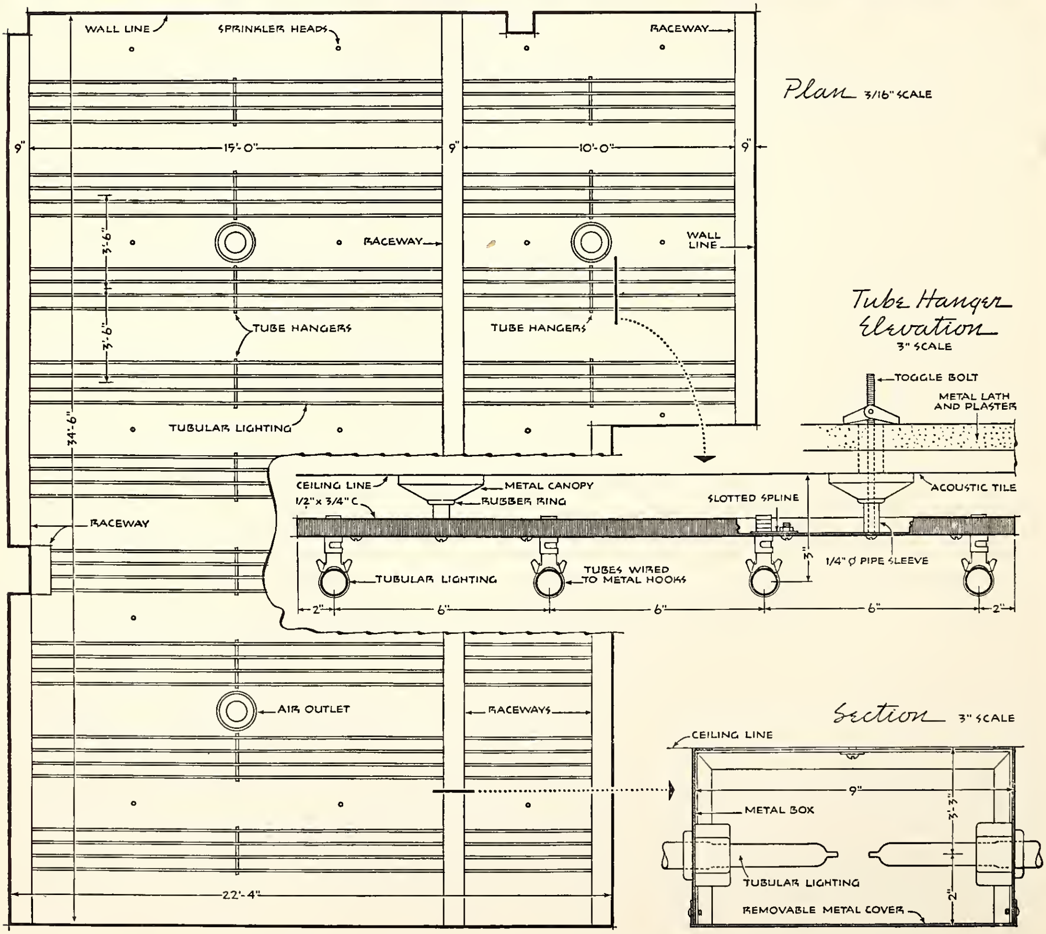
[11] *Tests made in collaboration with Prof. Jamison R. Harrison of Boston College, Chestnut Hill, Boston, Mass., and R. A. Coradeschi.*

[12] Resources for Freedom, A Report to the President by the President's Materials Policy Commission, *United States Government Printing Office, Washington, D. C. (June 1952)*

Factory: Ceiling Lighting





ZEON ELECTRICAL PRODUCTS CORP., Los Angeles, Calif.   THE AUSTIN COMPANY, ENGINEERS & BUILDERS

Cold-Cathode Fluorescent Lighting

BY BERNARD F. GREENE*

All of the lamp lengths listed below are available in a 20 millimeter (approximately ¾-inch) diameter lamp. The lumen output of the 20 millimeter lamp is about nine percent greater than that of the 25 millimeter lamp.

Table 1: Photometric Data for Standard Cold Cathode Lamps

FLA LAMP TYPE	Lamp Size		Rated Life Hours	Lamp Watts	Lamp Current Amps.	Warm White		3500° W		Daylight		Soft White	
	Diam. MM. (1)	Length Inch.				Lumens (2)	Brightness c/in^2 (3)	Lumens (2)	Brightness c/in^2 (3)	Lumens (2)	Brightness c/in^2 (3)	Lumens (2)	Brightness c/in^2 (3)
2593	25	93	15,000	43	.120	2300	2.9	2150	2.7	1950	2.4	1600	2.0
				41	.100	2200	2.8	2050	2.6	1850	2.3	1500	1.9
				22	.050	1150	1.4	1100	1.3	1000	1.2	800	1.0
2584	25	84	15,000	41	.120	2000	2.8	1900	2.7	1700	2.4	1400	2.0
				39	.100	1900	2.7	1800	2.5	1600	2.2	1300	1.8
				21	.050	1000	1.4	950	1.3	850	1.2	700	1.0
2576	25	76	15,000	40	.120	1750	2.7	1650	2.6	1500	2.3	1200	1.9
				38	.100	1650	2.6	1550	2.4	1400	2.2	1150	1.8
				19	.050	900	1.4	850	1.3	750	1.1	600	0.9
2564	25	64	15,000	38	.120	1350	2.5	1250	2.3	1150	2.1	950	1.8
				35	.100	1300	2.4	1200	2.2	1100	2.0	900	1.7
				18	.050	700	1.3	650	1.2	600	1.1	500	0.9
2552	25	52	15,000	34	.120	1000	2.4	950	2.2	850	2.0	700	1.6
				30	.100	950	2.2	900	2.1	800	1.9	650	1.5
				16	.050	500	1.2	450	1.0	450	1.0	350	0.8

(1) 25 mm = approx. 1 inch; 20 mm = approx. ¾ inch.

(2) Average initial rating after 100 hours operation 7000 hour rating approx. 77 percent of initial rating. Based on averages of manufacturers published catalogue data.

(3) Brightness values in candles per square inch: 1 c/in^2 = 452 foot lamberts.

Cold cathode designates a type of fluorescent lamp; to all outside appearances it looks the same and produces the same type of light as other fluorescent sources. The chief difference between cold cathode, preheat start, and slim line fluorescent lamps is found in the type of electrodes used in their manufacture. The cold cathode is in the form of a small metal thimble which is about one inch long and is internally connected to the lamp base. These thimbles are made from a special iron which operates at a relatively cool temperature and results in the special qualities inherent in cold cathode fluorescent lighting.

history

The history and development of cold cathode interior lighting lamps can be traced back through a related medium — colored and fluorescent tubes used for electrical display, electrical advertising, and ornamental lighting purposes. As early as 1904, D. McFarlen Moore installed a single tube about 180 feet long within which a discharge took place between cold cathode electrodes through carbon dioxide or nitrogen gas.

The next significant step in the development of cold cathode, which led to the establishment of the sign industry, was made by Georges Claude in 1910 when inert gases such as neon, argon, helium, krypton, and zenon were first used in electric discharge tubes. In 1938, progress made in the production of fluorescent phosphors led to the large scale commercial introduction of cold cathode fluorescent lighting.

lamp life

One of the most significant advantages of cold cathode is the extremely long life of the light source. At present, the life rating of the cold cathode lamp, as established by the Fluorescent Lighting Association, is 15,000 hours; after this time interval, it is predicted that approximately 10 to 15 percent of all lamps in a given group would be out. On a basis of life rating similar to that used by the hot cathode industry (the point at which 50 percent of the lamps in any group would be out), the expected life rating of the cold cathode lamp is greater than 25,000 hours.

The cold cathode lamp lights instantly and its life is not affected by the number of starts. Many installations in which cold cathode lamps have been used on a blinking cycle have been operating satisfactorily for 10 years. No method of accelerating the life of fluorescent lamps for testing purposes has ever been developed; as a result, up to 10 years transpire before test results can be established. Records are just now becoming available on cold cathode lamps which were installed from 7 to 10 years ago and are still giving satisfactory performance.

lamp brightness

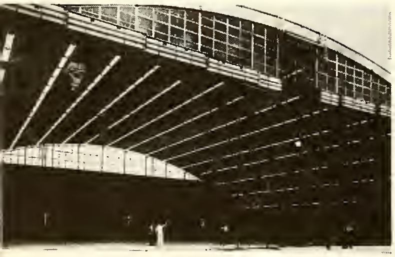
Cold cathode light sources, because of the type of electrodes employed, operate at maximum efficiency as low brightness sources; the most popular ratings are in the 100 to 150 milliampere range. At these values, the standard 8 foot, 25 millimeter diameter (approximately one inch) lamp operates with a brightness of less than 2.7 candles per square inch.

**Consulting Engineer; Technical Consultant, Fluorescent Lighting Association, New York, N. Y.*

Table 2: Number of Standard Lamps Connected in Series to Each Transformer

TRANSFORMER RATING			STANDARD LAMP DESIGNATIONS										
Open Circuit Volts	Short Circuit Amps.	Watts	Lamp Current Amps.	2052	2064	2076	2084	2093	2552	2564	2576	2584	2593
12,000	.120	580	.100	18	14	12	11	10	22	18	15	14	12
		630	.090	22	18	15	14	12	27	21	18	16	14
9000	.120	430	.100	12	10	9	8	7	15	12	11	10	9
		470	.090	15	12	11	10	9	20	16	13	12	11
7500	.120	350	.100	12	10	8	7	6	13	11	9	8	7
		400	.090	15	12	10	9	8	15	12	11	10	9
6000	.120	260	.100	10	8	7	6	5	12	10	8	7	6
		310	.090	12	10	8	7	6	13	11	9	8	7
5000	.120	260	.100	9	7	6	5	4	10	8	7	6	5
		260	.090	10	8	7	6	5	12	10	8	7	6

Transformer sizes also available in other short circuit ratings frequencies, and voltages. For 60 MA lamp short circuits ratings, the same open circuit voltage, and the same loading, the lamp currents are approximately 50% of those shown above.



Above, top: discomfort from glare, the result of a reflected image of the light source from shiny paper, has been eliminated in this drafting room through the use of cold cathode which has a low brightness source. Installations by this manufacturer are said to operate effectively on 25 cycles without discomfort of flickering. *Photo: Photographic Arts; installation by Q.R.S. Fluorescent Lighting Corporation, Toronto, Canada.*

Above, bottom: 350 cold cathode units, mounted at ceiling height in this hangar, produce 15 foot candles of shadowless light at the wing level of DC-6 planes which are serviced here. Although there is a wide variation in temperature and atmospheric conditions, this installation provides excellent light distribution and solves a difficult maintenance problem. *Installation by Colonial Electric Products, Incorporated, East Paterson, N. J.*

This low brightness lamp is adaptable to a wide range of applications using bare tubes; in many instances the cold cathode bare tube installations produce a brightness contrast less than that obtained by the use of the preheat type of fluorescent lamp with louver or glass attachments. For the same brightness contrast, the overall efficiency for the bare tube cold cathode source is higher than that of the shielded unit.

glare

Discomfort from glare is the result of high brightness contrast between the light source or its mirrored image and the surrounds of the task. The ways to reduce this contrast are to shield the source or to start with a low brightness source. Recent tests have indicated that the discomfort caused by most fluorescent lighting installations is the result of the reflected image of the light source from shiny paper or glass-topped desks. Since it is not always possible to control the sheen of the reading and writing surfaces, it is necessary to reduce the brightness at its source. This can only be done with the use of a diffusing medium, or by the initial use of a low brightness source such as a cold cathode fluorescent lamp.

lumen maintenance

All fluorescent light sources lose part of their initial light output after they have been operating for some time. Experience indicates that the rate of light loss depends upon the initial lamp brightness. It follows, therefore, that a low brightness source such as cold cathode fluorescent has a surprisingly low rate of light loss. At the end of 10,000 hours of operation, the light output of a cold cathode lamp is in the order of 74 percent of its original 100 hours rating, while at the end of 20,000 hours, the light output is 65 percent of the 100 hour rating. The lumen maintenance of the cold cathode lamp after about 15,000 hours of operation is approximately eight-tenths of one percent for each 1000 hours of operation. Based on these figures of lumen maintenance, it can be shown that for normal commercial or industrial uses it is economical to use the source in the order of 25,000 hours and then to group-replace the installation at this time.

lamp efficiency

Cold cathode lamp efficiency is about three to four times that of the incandescent source. Compared to the hot cathode, the initial efficiency of the cold cathode source is slightly lower; however, this difference is soon offset because of the higher lumen maintenance.

standardization

Standard types and sizes of cold cathode lamps have been established by the American Standards Association. These standard lamps are available from any of the established cold cathode lamp manufacturers throughout the country. The types, sizes, and standard photometric data are given in Table 1.

flexibility

In addition to standardized cold cathode lamps, a wide range of custom sizes and types is available. One of the chief attributes of the cold cathode source is its flexibility. For special installations, it is possible to obtain lamps in many diameters, wattages, lengths, colors, and shapes. Lamps can be bent around corners or curves, made to any pattern, or made to suit any particular purpose.

operating range

The cold cathode lamp is adaptable through a wide range of temperature and humidity conditions. By the use of ballasts having a secondary rating of 900 volts, these lamps have been successfully operated at temperatures of below freezing to above 120 F. When operating at extremely low temperatures, however, the light output of the lamp is below the rated value.

cold cathode lamp installation

There are generally two methods of installing a cold cathode light source. One of these, the ballast type of operation, is adapted to the standardized package installations; the other, the series circuit, is more widely used with standard or special types of lamps. The ballast type of operation is similar to that used with all fluorescent light sources. In this case, a single, double, or four-lamp ballast is mounted in a fixture. The entire unit comes complete and ready for mounting over an existing outlet or for direct connection to the source of electrical energy. The popular ratings of ballast in this type of installations are 50 or 60 cycles and/or 110-125 volts and 220-250 volts.

The series circuit arrangement for installing cold cathode fluorescent lamps can be likened to a chain in which each lamp is connected through the socket to the adjoining lamp. One large transformer serves all of the lamps in a circuit and up to 14 eight-foot lamps can be employed. The advantage of this sort of installation is that a minimum amount of wiring is required and the transformer can be located outside of the immediate area of the lamps. This arrangement is particularly suited to cove lighting or to instances where long lamp runs are involved.

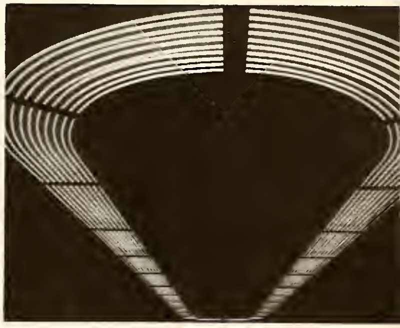
The size and rating of the transformer determines the number of lamps which can be connected in the circuit. Transformers are rated in terms of voltage and current; it is the voltage value which determines how many lamps can be connected to each transformer while the current is indicative of the lamp brightness. The number of standard lamps which can be connected to different transformer types is given in Table 2.

lamp dimming

The cold cathode source is the only fluorescent lamp which is adaptable to dimming. Where dimming is required, the usual procedure is to install the lamps on a series type of installation and to connect any of the conventional types of dimmers to the low voltage side of the transformer. With this type of installation, lamps can be dimmed down to 10 percent of the full rated light output.

Left: diffused by eggcrate louvers, a four 25 millimeter diameter tube installation provides an average of 40 foot candles throughout this office area. The flexibility of the tubing easily conforms to the architectural requirements of the ceiling.

Below: this picture strikingly demonstrates the flexibility of bare tube cold cathode installations. Employing 25 millimeter warm white tubes this lighting effectively illuminates a men's clothing store. *Both photos: Jacob Stelman; installation by Cutler Light Manufacturing Company, Philadelphia, Pa.*



where to use cold cathode

The properties of low brightness, instant start, extremely long life, and others, make the cold cathode lamp adaptable to numerous installations. Wherever a long fluorescent lamp (four feet or more) can be employed, cold cathode fluorescent is applicable. In this country it has been installed in all types of stores, industrial plants, office buildings, schools, and theaters. Its use is not restricted to this country alone: as a matter of fact in most other countries throughout the world cold cathode fluorescent is the favored form of lighting.

Where maintenance of the light source is a problem, this lighting method is particularly well suited. In the Detroit school system, where a difficult maintenance problem existed, cold cathode lamps were installed and after operating for several years the lamp replacement was found to average less than one lamp per hundred per year.

The immediate cost of a lighting system is in many instances a determining factor in the choice of the system used. For this reason, the use of cold cathode is ruled out—for the calculated cost per light unit with cold cathode is higher than for most other lighting systems. However, if the cost of the installation is taken over a period of time—or if the installations are compared on the basis of equal quality of light, i.e. brightness—then it can be shown that the cost favors the use of cold cathode.

Above: this conventional type of cold cathode installation consisting of two rows of six-lamp units 48 feet long provides an average light intensity of 100 foot candles over the counters. The dimensions of this market are 20 feet x 55 feet with a 10 foot ceiling height. *Photo: D. L. Hopwood; installation by Morton Neon Company, Denver, Colo.*

WATER SUPPLY AND LABORATORY PLUMBING

Provision of potable water is a fundamental requirement of any community. Some cities are able to take advantage of relatively nearby supply sources, such as lakes and rivers, while others must rely on more distant sources or those beneath the ground. One of the great Municipal Filtration Plants is located in Chicago's South District where more than 500 million gallons a day are processed. At this plant, raw water is taken either from an off-shore crib or from direct lake ports and then pumped to immense mixing basins where appropriate chemicals are added. The water is next directed to settling basins and filters before arriving at the huge filtered-water reservoirs that not only serve over one and one-half million citizens but also all of the local industrial requirements. Often, however, no municipal supply exists when a new community of buildings is planned and the architect, as advisor to the owner, must be prepared to make recommendations and bring up considerations governing the provision of water. In the following article, "Water Sources and Treatment for Private Systems," William J. McGuinness offers an excellent check list of considerations for structures to be built beyond the limits of the municipal system.

One of the best integrated laboratory buildings is the John Dorrance Laboratory of Biology and Food Technology at M.I.T. A study of its plan and section immediately informs one how efficiently this structure accommodates its mechanial services. In the narrow, rectangular plan, longitudinal double girders are dropped below the transverse beams providing between them continuous, vertical chases from basement to penthouse, for exhaust ducts and other services. This design conveniently allows ventilating ducts, piping, and so on to branch off at the ceiling line without interruption by the structural members. In "Laboratory Plumbing" (*page 365*), John Edmund York describes the component mechanical services that must be provided for the modern laboratory and how they should be designed for maximum efficient service.

Water Sources and Treatment for Private Systems

BY WILLIAM J. McGUINNESS*

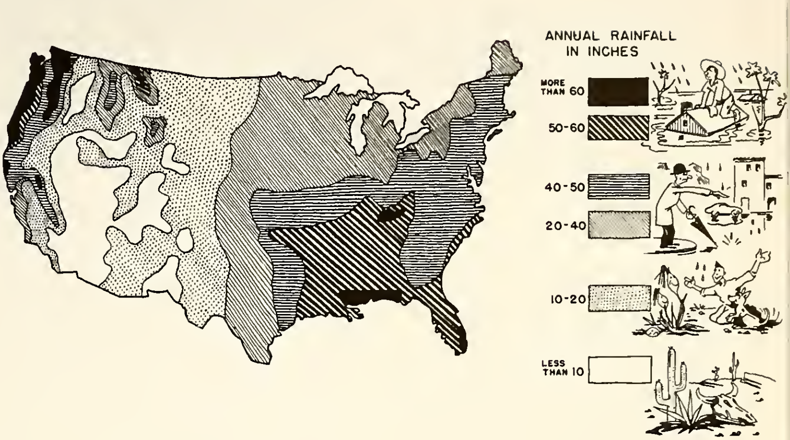


Figure 1: records of the United States Geological Survey are useful in finding the average annual rainfall in any part of the country. Surface water resulting from this precipitation may vary a great deal in any given location and in some cases will be undependable for use by a small, private consumer. Ground water reached by wells, while also dependent upon the rainfall, is somewhat more constant in level and yield. Easier treatment problems also generally recommend the use of ground water.

Role of the Architect

When a community or building is planned for an area where no municipal water supply exists, problems frequently arise in obtaining water of adequate quantity and acceptable quality. As the advisor of the owner, the architect often guides the investigations for the solution of such problems. The procedure includes the procuring of chemical and bacteriological analyses of the water, drilling to water-bearing strata that will assure a proper yield, the selection of suitable piping material, and the choice of proper pumps and treatment processes. In areas where conditions are doubtful, such studies should be initiated at the proposed location before site conditions are fixed. Following an approval of the site and the volume and nature of the supply, decisions must be made concerning the need for softening, purification, and the correction of other possible detrimental qualities for the benefit of occupants, equipment, and piping.

Recently a large number of architects were questioned about the extent of their practice beyond city water supply. Almost all of them had designed buildings (schools, hospitals, residences) in such areas since 1945, and a great majority of them had been called upon to recommend a well-driller, a pumping system, and apparatus for treatment. Many factors have served to increase the number of projects built away from city water supply. Industries have shown a tendency to move from urban to rural communities. For many owners this has resulted in lower taxes and happier labor relations; water problems, however, have increased. Fast growing communities, even in close proximity to established water companies, have found that their needs often exceeded the resources of the general public supply. A committee of the American Society of Civil Engineers, following two years of study, has stressed the difficulty faced by water works in meeting the greatly increased post-war demand. Equipment was unimproved during the war, and until recently, held back by the industrial lag following the war. The installation of air conditioning often calls for a private source of cool water even in buildings otherwise supplied from city mains. In these cases the need is for great quantities of water which will be used and then dispersed back into the ground. It is sometimes more economical to provide a private well for this purpose than to buy city water in the quantities required. Often this water must be treated in areas where the hardness of the water would result in the deposit of scale on the equipment. In the case of corrosive waters, treatment is equally necessary to save piping from destruction or clogging by rust. Occasionally the general needs of a building are such that a private supply may prove more economical than city water even though the city supply is directly available.

Water Sources in General

Water may be taken from a number of sources; its quantity and quality vary accordingly. Rainfall may be caught on roofs or other specially prepared areas and then stored in cisterns. Bermuda uses this system because of the porosity of the coral below grade and the general proximity to the sea. Wells in this soil are brackish. Rain water is soft and pure but the process of collection and storage is difficult. Outcroppings such as artesian wells and springs may be utilized but their yield is sometimes undependable. Many large cities, New York for example, make use of normally abundant supplies from lakes and rivers. These waters are rendered pure and palatable by aeration, filtration, and chlorination. Under the control of a large city such treatment is entirely practicable, but for the use of an isolated building, well water is preferable. Its use minimizes the possibility of pollution and the unpleasantness of turbidity, odor, and color. The abundance of ground water is dependent upon the mean annual rainfall and the proximity of the site to the points at which such precipitation collects. Figure 1 shows the variation of rainfall in the United States, from areas

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**Professor of Architecture, Pratt Institute, Brooklyn, N. Y.*

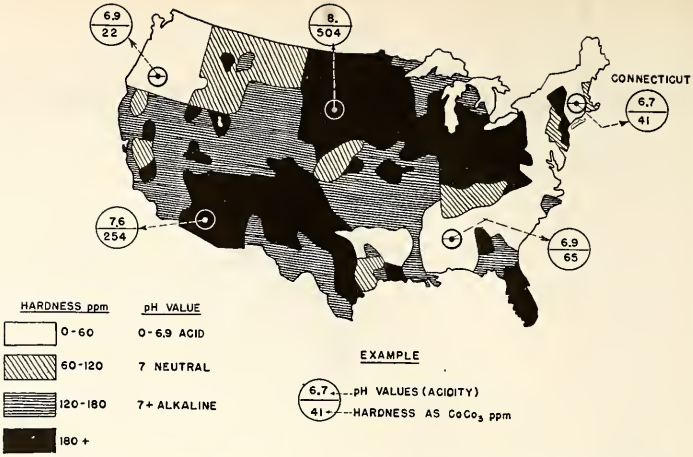


Figure 2: water is either alkaline, neutral, or acid. Alkaline water is frequently hard and will clog pipes with an insoluble deposit. Acid water causes corrosion. Both of these conditions require correction. Neutral water may be used directly without treatment. Surface water is usually soft. Ground water is often hard but may in some cases have an acid reaction instead.

TABLE 1: WATER QUALITY PROBLEMS AND THEIR CORRECTION IN PRIVATE SYSTEMS

item	cause	bad effect	correction
Hardness	Calcium and magnesium salts from underground flow	Clogging of pipes by scale, burning out of boilers, and impaired laundry and food preparation	Ion exchanger (Zeolite process)
Corrosion	Acidity, entrained oxygen and carbon dioxide, (low pH)	Closing of iron pipe by rust, destruction of brass pipe	Raising the alkaline content (Neutralizer)
Pollution	Contamination by organic matter or sewage	Disease	Chlorination by sodium hypochlorite or chlorine gas.
Color	Iron and manganese	Discoloration of fixtures and laundry	Precipitation by filtration through manganese zeolite (Oxidizing filter)
* Taste and Odor	Organic matter	Unpleasantness	Filtration through activated carbon (Purifier)
* Turbidity	Silt or suspended matter picked up in surface or near-surface flow	Unpleasantness	Filtration

* Note: These problems are not common in private systems using deep wells

with less than 10 inches annually to those with 60 inches or more. The extreme of aridity is found in the southwest and that of abundance around the mouth of the Mississippi and in the northwest. Long Island is an example of a location providing abundant ground water. The water table is encountered at depths varying from 5 to 30 feet. It is possible to pump water in almost any quantity. It is pure and requires little treatment. In the southwest water is difficult to find. In this region communities are likely to develop around acceptable sources. Ground water levels throughout the country remain quite stable. In spite of the drought which occurred in some parts of the country in 1947, there was no nation-wide decline in ground water level and many states maintained levels at or above their average position. As to fluctuations during the year, many locations maintain a water table with a variation of less than a foot; others vary as much as 20 feet. This is not considerable since it is usual to count on a well which taps a fairly deep stratum to guarantee quantity and purity. Underground conditions should be investigated from the experience of well-drillers long established in the vicinity. The records of the state and of the United States Geological Survey are also valuable for this purpose. In Figure 2 it will be noted that hard waters are usually found in areas where water is scarce (compare with Figure 1). Such waters are taken from deep levels after flow through minerals. Where water is abundant acidity is most common because of the entrainment of oxygen and carbon dioxide during flow at or near the ground surface level.

Investigation for Yield of Wells

The amount of water in gallons per minute that needs to be taken from a proposed well is set by the requirements of the building to be supplied. Usually a large storage tank is used to supplement the delivery of the pump during peak hours. The pump has a capacity sufficient for the "average" hour. It is logical that the pump should not run continuously and also that it should not fall behind in its job. A margin of safety and the possibility of expansion should be considered. In districts where there are numerous wells, the records of well-drillers are very informative. They may indicate the kind of strata to be encountered and the possible yield and quality of the water. Where such records do not exist it is necessary just to go ahead and drill. Upon reaching a trial level it is possible to make a test to determine whether the desired flow is obtainable. If it is not, the well may be "developed" or sunk to a lower level. Figure 3 indicates schematically the method of making a yield test. The orifice meter shown is a 6-inch diameter pipe with a 4-inch diameter orifice. A water-tube let into the side of the pipe measures the pressure in inches of water above the center of the pipe. This is referred to as a 6" x 4" orifice and it is one of many, varying from 4" x 2½" to 10" x 8" for various yields. The chart applying to the 6" x 4" orifice is shown in the same figure. On this curve may be read the yield for any pressure shown on the tube. Thus, for 9 inches of water the flow is 200 gallons per minute. The hookup consists of a pump connected to the well and discharging water freely through the orifice a few feet above the ground. The orifice must flow full. This test may be run for 24 hours or more to give assurance of a sustained yield for the needs of the

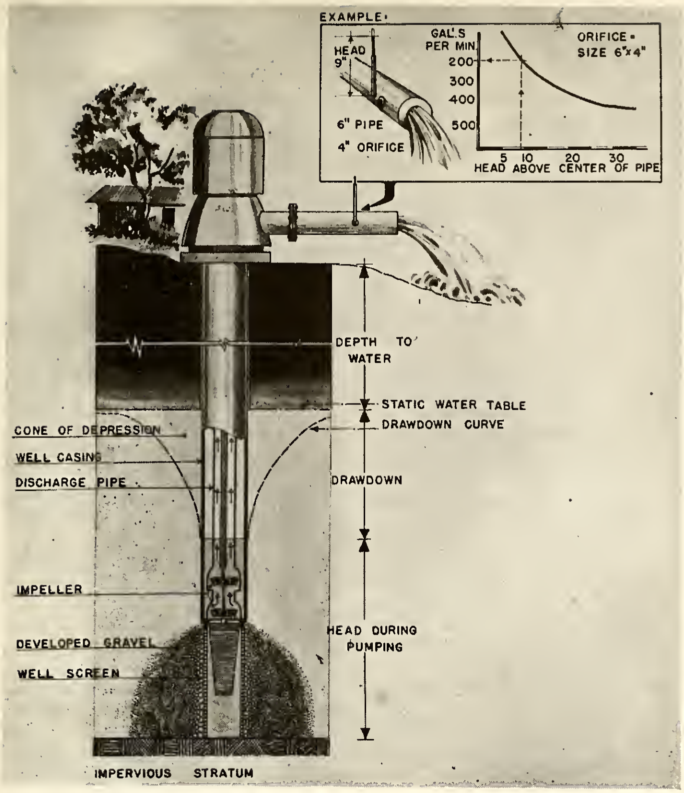


Figure 3: following the decision to drill a well and the discovery of the distance down to water, it is necessary to try the pump in operation. Sufficient water must be constantly available. The drawdown during operation must not be excessive. A small drawdown will call for less power and will give more assurance of constant flow.

proposed building. During the test it is necessary to measure the depth to the water level during pumping. From this and the depth to the static water level (previously determined), it is possible to compute the "drawdown." It is desirable to have the water level as high as possible while pumping; it reduces the power needed and guarantees the supply of water to the well screen in the event of fluctuation resulting in the dropping of the water table. A number of methods are used for finding the depth to water, including the observation of the wetted length of a weighted tape lowered into the well and pulled up for inspection.

Investigation and Correction for Quality

Table 1 lists the difficulties that may be encountered in private water systems; it describes their bad effects and the methods of correction. Most of these items will be evident in a chemical analysis. For example, a report for a well at a large residence in Connecticut pointed to an acid reaction. The water is now being treated to correct this condition; hardness presented no problem. Both the pH indicating acidity and the total hardness in the report agreed substantially with the more general indication for the State of Connecticut given in the map shown in Figure 2. Notwithstanding the aid of such general guides, specific tests should be made at every proposed well and continued periodically. Water laboratories and treatment equipment manufacturers may be retained to make such tests. An equally important matter is polution, which is shown in a bacteriological test obtainable from the State Health Department. This too should be repeated periodically to guard against sudden change which might result in disease or epidemic.

Hardness

When alkalinity exists in the form of calcium and magnesium salts, as it usually does from flow in limestone and other mineral deposits, hard water results; this is probably the most common problem in water treatment. These salts deposit in pipes and equipment forming an insoluble scale which can close up pipes within a period of a few years. The action is accelerated by heat, so hot water pipes are most vulnerable. In boilers the scale changes the heat-transfer qualities of boiler tubes and causes them to burn through. Hardness is costly in every respect; it makes laundering difficult because soap will not lather properly and because there is an insoluble deposit on clothing. Similar difficulties occur in dishwashing and personal bathing. Vegetables prepared with hard water are often tough and unpalatable. Various degrees of hardness are encountered. The approximate low and high limits are 10 parts per million and 1800 parts per million. Waters containing over about 65 parts per million require treatment. Water for high-pressure boilers, however, should have even this small amount of hardness removed. Reference to Figure 2 will indicate that in many parts of the United States the use of water without treatment is almost impossible. The zeolite process is the one commonly used for softening water; its action is indicated in Figure 4. A zeolite softener contains a bed of ion exchange material which removes the calcium and magnesium from the water and replaces them with an equivalent amount of sodium. Periodically the softener is regenerated to restore its softening capacity. The ion exchange bed is first backwashed to remove dirt and suspended matter caught on the top of the bed. A solution of common salt is then introduced to restore the sodium content of the ion exchanger and displace the calcium and magnesium which are flushed to waste in the rinsing step that follows.

Acidity

Soft waters are acid in reaction and will attack pipes and equipment. In some industrial communities acid wastes find their way into the water causing this condition. More frequently the dissolved carbon dioxide or oxygen are the causes of acidity. Iron pipes oxidize or rust on the inside when handling this kind of water. The oxide is 10 to 15 times the volume of the metal that formed it and so will quickly fill the pipe. Non-ferrous pipes are eaten away or "de-zincified." The acid attacks the zinc which is alloyed with copper to make brass. Although copper is the best material to use for pipes handling this kind of water, often enough the copper will dissolve in the water to cause green or blue stains on plumbing fixtures or on laundry. Treatment is the safest solution. It is accomplished by a neutralizing filter shown in Figure 4, the action being to change the acid condition to an alkaline one.

Pollution

Water-carrying bacteria injurious to health is not usually encountered in supplies using deep wells as a source. When, however, bacteriological examinations indicate the need for purification, small amounts of chlorine will accomplish the required result. In small installations sodium hypochlorite powder is used for this purpose and in large installations chlorine gas in cylinders is used. Figure 4 includes a gas chlorination unit and indicates the connection of the chlorine solution to the suction side of the supply insuring the proper correction of all water entering the premises. Many hospitals and other institutions where health is a matter of vital concern have standby units ready in case the presence of harmful bacteria should be detected at any time.

Color

While color caused by organic matter is rarely found in deep wells, soluble iron compounds often find their way into supplies and upon oxidizing form a red deposit on plumbing fixtures. This can be avoided by passing the water through an oxidizing filter which oxidizes the soluble ferrous oxide to insoluble ferric oxide and catches it in a filter bed.

Taste and Odor

Well water is usually free of these two troubles which are caused by organic matter. They can be corrected, when found, by passing the water through a filter of activated carbon which picks up odor and taste.

Turbidity

The analysis report for the Connecticut well, previously mentioned, shows an absence of turbidity and sediment. This is the usual case with well water. Surface supplies on the other hand require coagulating equipment and filters to pick up suspended matter, etc., which is carried in by the water. The small amount that may be carried by well water will seldom require a filter. Where a filter is used for any of the other processes described herein a filtering action is provided which will clear up any small amount of sediment. The exception to this is the purifying or activated carbon filter which is too porous to hold suspended matter. All filters need periodic cleaning and backwashing.

The Development of Wells

County or municipal health authorities usually specify a minimum distance from the proposed location of any well to the position of any cesspool or septic tank. It may also be necessary to obtain a permit from a state conservation commission whose interest it is to maintain the water

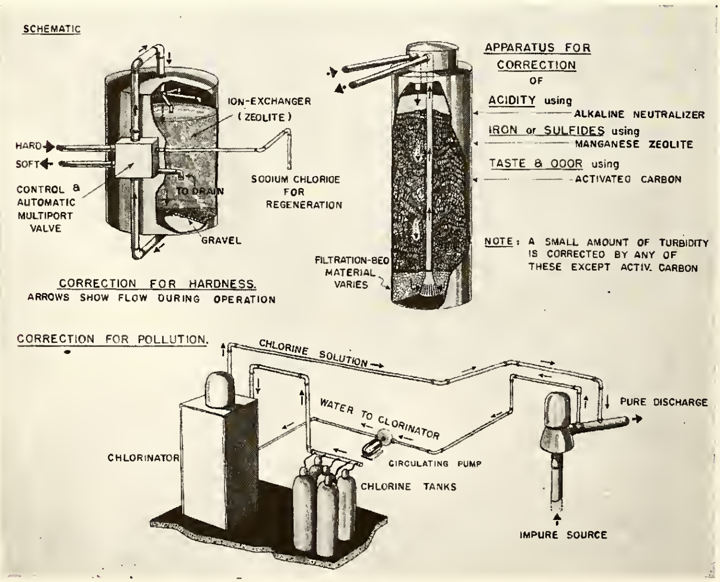


Figure 4: hardness yields to treatment in an ion-exchanger. Soft water results. The hardness is deposited in the filter. The exchanger may be back washed and regenerated. Iron and sulphides are removed by manganese zeolite. Acid may be neutralized. Taste and odor may be removed by activated carbon. Impure supply may be corrected by chlorine gas as shown or in smaller installations by a hypochlorinator using a powder.

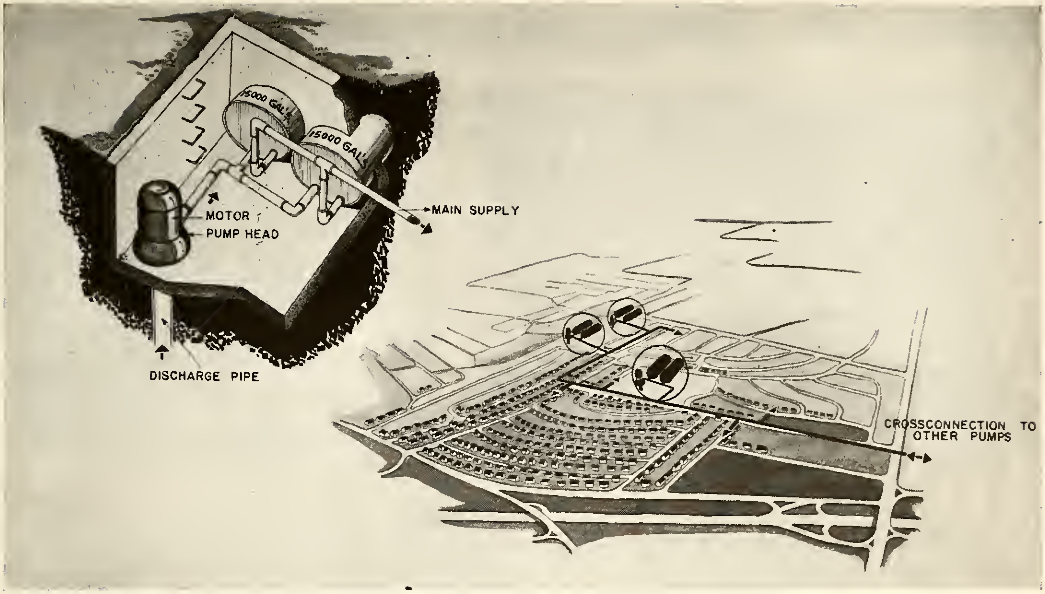


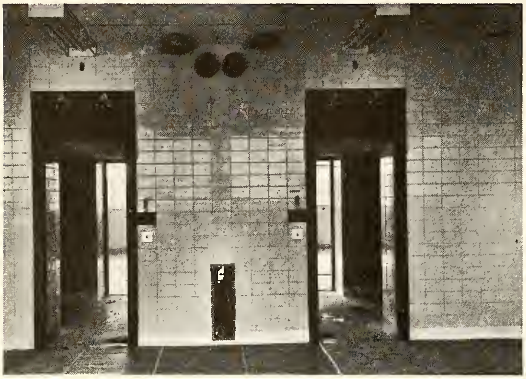
Figure 5: the speed of the construction of Levittown outstripped the resources of the general public supply. This illustration shows about one third of the development and three of the ten pumping stations and wells. All water is obtained within the area. Mains are cross connected.

table and prevent its being lowered by excessive pumping. All details of the installation must be given, including the result of pumping tests, measurements to static water level, amount of drawdown, etc. Wells can be developed or improved if they do not have sufficient flow or if the drawdown is excessive. This is accomplished by removing the fine material in the sand and gravel bed surrounding the well screen. This fine material is washed out by means of a surge plunger which is moved up and down. By means of this reverse flow, much sand is dislodged and flows out of the well. Special patented compressed air processes are used to a similar end. A certain amount of this development is always necessary to prevent the well from supplying gritty water for a long period at the beginning of operations. This gritty condition would result in unsatisfactory water and in serious damage to the pump. Other things that affect the flow and drawdown are the diameter and the length of the well screen.

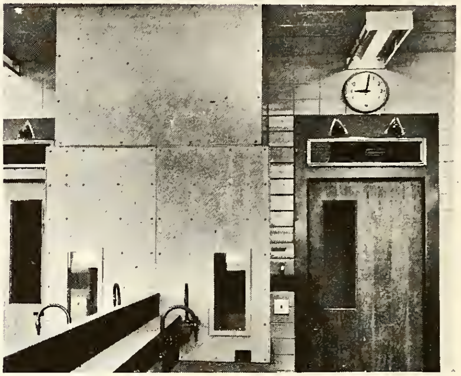
Typical Installation

Figure 5 shows a typical private water system installed to supply the Levittown residential community on Long Island, New York. It represents about one-third of the development and shows three of the ten pumps and some of the water mains. Here conditions of drilling, yield, and quality of water are ideal. The development's 10,000 homes plus shopping and community facilities are supplied by 10 wells using 4- and 5-stage vertical turbine pumps similar in type to that shown in Figure 3. This is a type of pump almost universally used for deep wells having a large yield. The depth of the wells at Levittown varies from 95 to 350 feet and a typical well has the following general characteristics. The well casing is 12 inches in diameter and it houses an 8-inch multi-stage turbine pump. The delivery of the pump is about 1000 gallons per minute against a pressure of 80 pounds per square inch at the pump discharge, which insures an adequate pressure at the faucets. The pumps are electrically driven and some have breakdown power in the form of gasoline motors. These cut in upon electrical power failure or interruption. Each pump is called upon to supply about one million gallons per day. Static water level is found at a depth of about 20 feet. Well screens are 25 to 40 feet long and the wells are developed by means of surge plungers and backwashing as well as compressed air. Some of the wells are thus pumped and agitated for a week or more before putting them into service. Each pump delivers into two 15,000 gallon tanks. These discharge into 10-inch mains which are cross-connected to other pump-and-tank units. All tanks are steel and are below grade. They provide air cushions against the pumping operation. Pumps and tanks are housed in shelters together with control and record apparatus. There are no overhead tanks. Before accepting a well at a given depth, yield tests are run for 8 to 48 hours to give assurance of acceptable performance. Some of the wells are as close together as several hundred feet without appreciable effect of one on the drawdown or yield of the other. Conditions on Long Island consisting of high water table, water-bearing sand and gravel, and general purity of ground water make the problem of water supply an easy one. Water at Levittown is pumped directly to the mains without treatment. Unlike other Long Island wells, which used to supply Brooklyn, this water is not hard. The treatment of a slight acid condition is under consideration. Frequent tests are made to retain a constant check on these qualities and also on the sanitary condition of the supply.

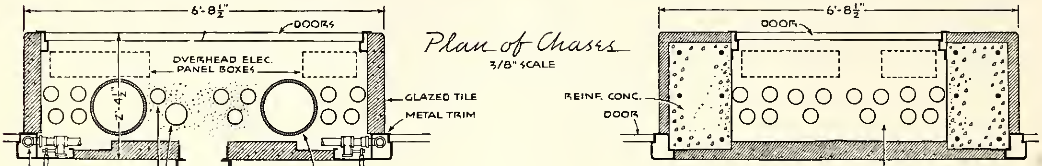
Chemical Engineering Building: Laboratory



TYPICAL CHASE WALL FROM LABORATORY SIDE



WALL WITH FUME HOOD ADDED



Plan of Chases
3/8" SCALE

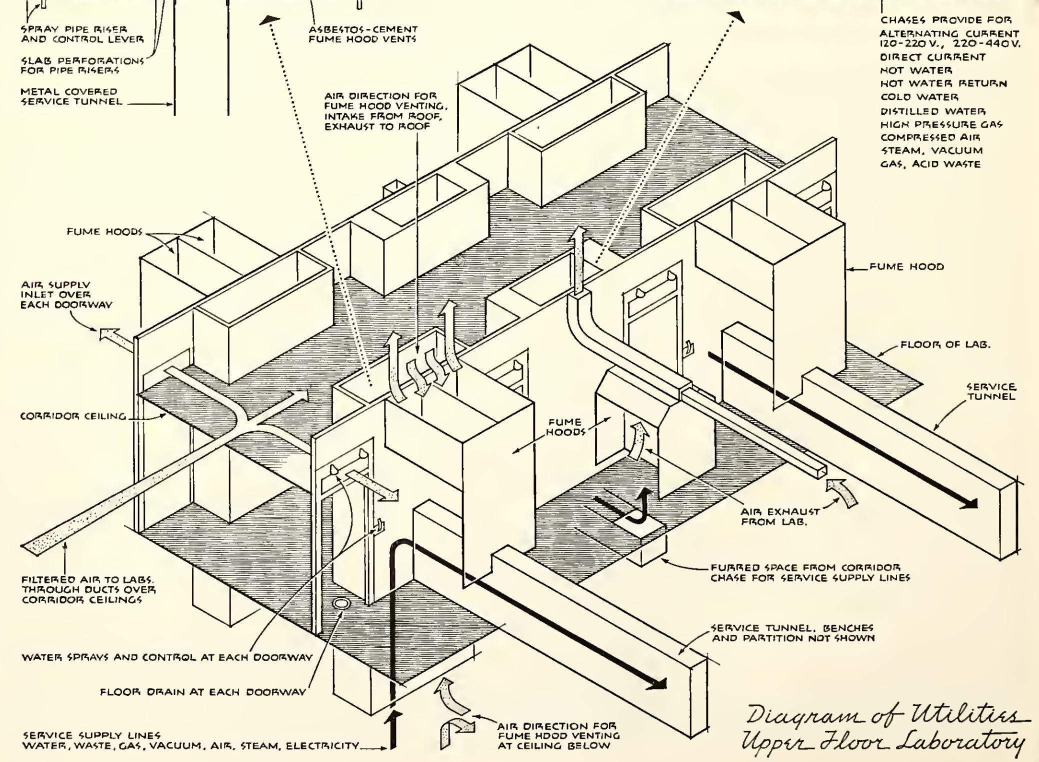

AIR DIRECTION FOR FUME HOOD VENTING, INTAKE FROM ROOF, EXHAUST TO ROOF
FUME HOODS
AIR SUPPLY INLET OVER EACH DOORWAY
CORRIDOR CEILING
FUME HOOD
FLOOR OF LAB.
SERVICE TUNNEL
FUME HOODS
AIR EXHAUST FROM LAB.
FILTERED AIR TO LABS. THROUGH DUCTS OVER CORRIDOR CEILINGS
FURRED SPACE FROM CORRIDOR CHASE FOR SERVICE SUPPLY LINES
SERVICE TUNNEL, BENCHES AND PARTITION NOT SHOWN
WATER SPRAYS AND CONTROL AT EACH DOORWAY
FLOOR DRAIN AT EACH DOORWAY
SERVICE SUPPLY LINES WATER, WASTE, GAS, VACUUM, AIR, STEAM, ELECTRICITY
AIR DIRECTION FOR FUME HOOD VENTING AT CEILING BELOW

Diagram of Utilities
Upper Floor Laboratory

Laboratory Plumbing

BY JOHN EDMUND YORK*

In addition to normal building services, a modern laboratory must be provided with some or all of the following services: steam, condensate, city water, nonpotable water, hot water, distilled or deionized water, high- and low-pressure compressed air, vacuum, gas, hydrogen, oxygen, nitrogen, hydrogen sulphide, waste lines, and refrigeration.

Laboratories may consist of a single room, many rooms in a specially constructed building, or intermediate arrangements.

The piping is an important part of a laboratory and should be given proper consideration in the preliminary stages of the design to avoid a makeshift appearance and to insure long, trouble-free service.

When building or equipping a laboratory it is always advisable to use the services of competent architects and engineers who are familiar with the special problems involved in this class of work. Before considering the general distribution system it will be advantageous to review briefly the individual services.

steam and condensate

Steam will generally be brought to the laboratory at higher pressures (*Figure 1*) than required for use within the building.

Pressure-reducing valves should be provided to deliver steam at pressures up to 15 psi for building heating, low-pressure laboratory services, and for heating water for washing laboratory glassware and equipment. The same pressure-reducing valve may be used for the latter two services.

Steam at pressures up to 30 psi may be required for stills and at the full available pressure for hot plates.

Condensate should be drained from equipment, mains, risers, and radiation through suitable traps and collected in a vented receiver from which it may be pumped back to the boiler.

Where frequent changes are not anticipated steam lines may be of black steel with welded joints, but where changes are probable screwed or flanged joints should be used.

Condensate lines may be of copper tubing with sweated joints or as described for steam lines.

water

City water should be supplied to all equipment which may be used for obtaining drinking water, washing of burns or wounds, preparation of food products or medical supplies.

Nonpotable water may be used for cooling and other services but no cross connections between city water and nonpotable water should be permitted.

Hot water may be supplied from a storage-type heater or an instantaneous-type heater (*Figure 2*). The latter will cost less, occupy less space, and can continuously supply hot water to the limit of its capacity, but it does not permit a close regulation of the temperature of the water as with a storage-type heater and requires larger steam supply.

For hot-water distribution through large buildings a gravity or forced-circulation system should be provided to insure delivery of hot water where needed without delay or waste of water.

With low buildings and long mains a small circulating pump should be provided on the return side of the system, to insure proper circulation. Sufficient water should be circulated to offset the heat loss through the system with a drop of not more than 5 to 10 degrees.

Water heaters and hot- and cold-water lines should be constructed of corrosion-resistant materials, preferably copper.

deionized and distilled water

For many laboratories mineral-free water is a satisfactory substitute for distilled

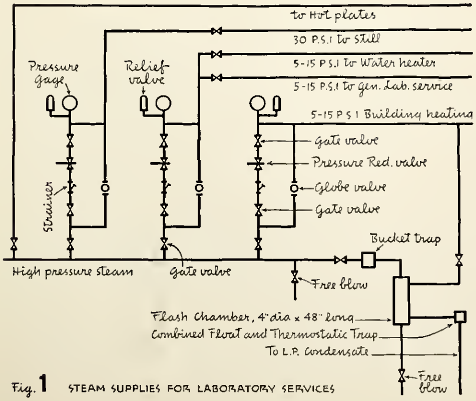


Fig. 1 STEAM SUPPLIES FOR LABORATORY SERVICES

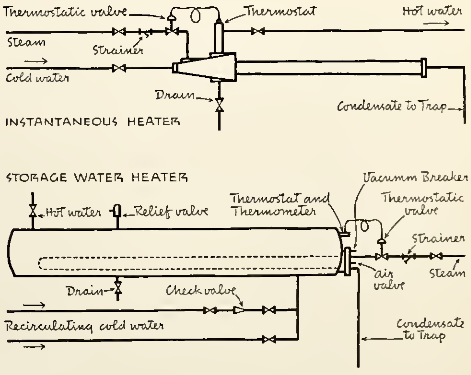


Fig. 2 COMPARATIVE INSTALLATIONS OF WATER HEATERS (SAME CAPACITY)

water and is much less expensive.

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* *Registered Professional Engineer, Massachusetts and New York*

The equipment for demineralizing or deionizing water causes it to flow through two alternately arranged beds of cation and anion resins. The cation resin attaches the dissolved metallic ions to itself and replaces them with hydrogen ions. Thus the dissolved salts are converted to their corresponding acids. The anion resin then absorbs these acids and delivers a mineral-free water. When the exchange capacity of the resins is exhausted they are regenerated without the use of heat by a low-cost regenerant solution.

If, in addition to being free from minerals, the water must also be free from organic, inorganic, gaseous, bacteriological, and pyrogenic impurities, a still may be used in which the water is first preheated and vented to remove the gases, and then converted into pure, dry steam by gently boiling, with the vapors disengaging at low velocities and then condensed in a tin-lined, vented condenser. Where extra purity is required, double or triple stills may be used.

If the deionized or distilled water is to be piped to several locations the materials for the piping system must have no effect on the water. Block tin, pyrex glass, or aluminum satisfy this requirement.

Before putting a distilled water system into use it should be thoroughly flushed out with city water and then with distilled water.

compressed air

Compressed air is commonly supplied to laboratory tables at 5 to 10 psi, at which pressure the ordinary laboratory cock will discharge 1½ cu ft of air per minute. For special purposes air at higher pressures may be required.

If both low- and high-pressure air are required, separate compressors should be used. Low-pressure air compressors may be either of the rotary or reciprocating type. For high pressures the reciprocating type is more commonly used and may be of the two-stage type with an intercooler. Compressors may be either air- or water-cooled, the latter being preferable, especially for high pressures.

Compressors should not be oversized, but for a limited number of cocks a compressor capable of supplying the full demand with all cocks in use may be provided. A receiver should always be provided to prevent too frequent starting and stopping of the compressor.

Clean, cool, dry air should be provided for the compressor and a filter and silencer should be installed on the inlet.

There should be no valves between the compressor and the receiver, and the receiver should be equipped with a pressure gage, relief and drain valves.

Where dry air is essential, high-pressure units should be furnished with an after-cooler.

Piping should be as specified for steam lines.

vacuum

For normal laboratory requirements vacuums from about 14 to 20 in. of mercury are adequate at the outlets. For special cases vacuums up to 28 in. or more may be required.

For vacuums from 14 to 20 in. a good grade of rotary-vacuum pump may be used. The size of the pump is a matter of good judgment rather than mathematical computation.

If the vacuum pump is to be operated automatically it is essential that it should not be oversized appreciably, as this will cause cycling unless special precautions are used to prevent this.

For maintaining the higher vacuums, a high-grade reciprocating pump may be used.

Piping should be as specified for steam lines. Where screwed joints are to be used care must be exercised in threading the piping in order to insure tight joints. After the line has been carefully made up, dissolved beeswax or varnish should be applied to the theaded joints while the system is under a vacuum to seal off any small leaks.

gas

Gas is normally supplied to a building at a pressure of about 6 in. of water; it may be manufactured gas with a calorific value of 550 Btu per cu ft or natural gas with a calorific value of 1000 Btu per cu ft. At 6 in. the flow through a standard gas cock will be about 14.5 cu ft per hr and at 3.5 in. (the minimum for satisfactory operation of Bunsen burners) about 8.5 cu ft per hr.

Gas-blowing equipment may require pressures up to 5 or 6 psi and rotary positive displacement gas boosters must be used.

Where a booster is used a mercury seal should be provided to prevent damage to the meter housing in case of excessive suction.

Where neither manufactured nor natural gas is available, propane or butane gas can be furnished in standard-sized cylinders containing the equivalent of 850 and 640 cu ft, respectively, at atmospheric pressure. The actual pressure in the cylinder in each case is 102 psi at 70 F.

Gas cylinders should, when possible, be installed out of doors and must be provided with regulators of an approved type to reduce the pressures to that required inside the building.

Piping should be black steel with screwed malleable or steel fittings, or welded joints. Joints for piping systems supplying propane or butane should be welded or brazed. Plug-type cocks should be used for stops. For the larger sizes these should be of the lubricated type.

oxygen, hydrogen, and nitrogen

These gases can also be obtained in standard-sized cylinders which may be installed in a similar manner to cylinders of propane and butane.

Oxygen cylinders and manifolds should be separated from cylinders and manifolds containing flammable gases by fire-resistant barriers, cylinders, manifolds, and so forth, should be kept free from oil or other combustible materials and pipe scale.

All parts of oxygen systems which are exposed to cylinder pressures should be constructed of nonferrous materials designed to withstand the very high pressures. Joints may be welded, soldered, or screwed and made up with litharge and glycerine.

The pressure in oxygen, hydrogen, and nitrogen cylinders at 70 F is 2000 psi and the cylinders contain approximately the equivalent of 200 cu ft of gas at atmospheric pressure.

All parts of hydrogen and nitrogen systems which are exposed to cylinder pressures should be constructed of extra-heavy steel pipe with forged steel fittings. Joints should preferably be welded and if screwed should be made up with litharge and glycerine.

Sharp dies should be used to insure perfect threads on screwed piping. Before placing a piping system in service it should be tested with air to 1½ times the maximum pressure. After testing, oxygen systems should be washed out with a suitable nonflammable solution such as caustic soda or trisodium phosphate and then steamed out thoroughly to remove all dirt and grease. Valves should be dismantled and thoroughly cleaned in a similar manner.

hydrogen sulphide

Hydrogen sulphide is an extremely poisonous gas and has a very unpleasant odor. It is supplied in cylinders having a capacity of approximately 1000 cu ft at atmospheric pressure and it has a pressure of

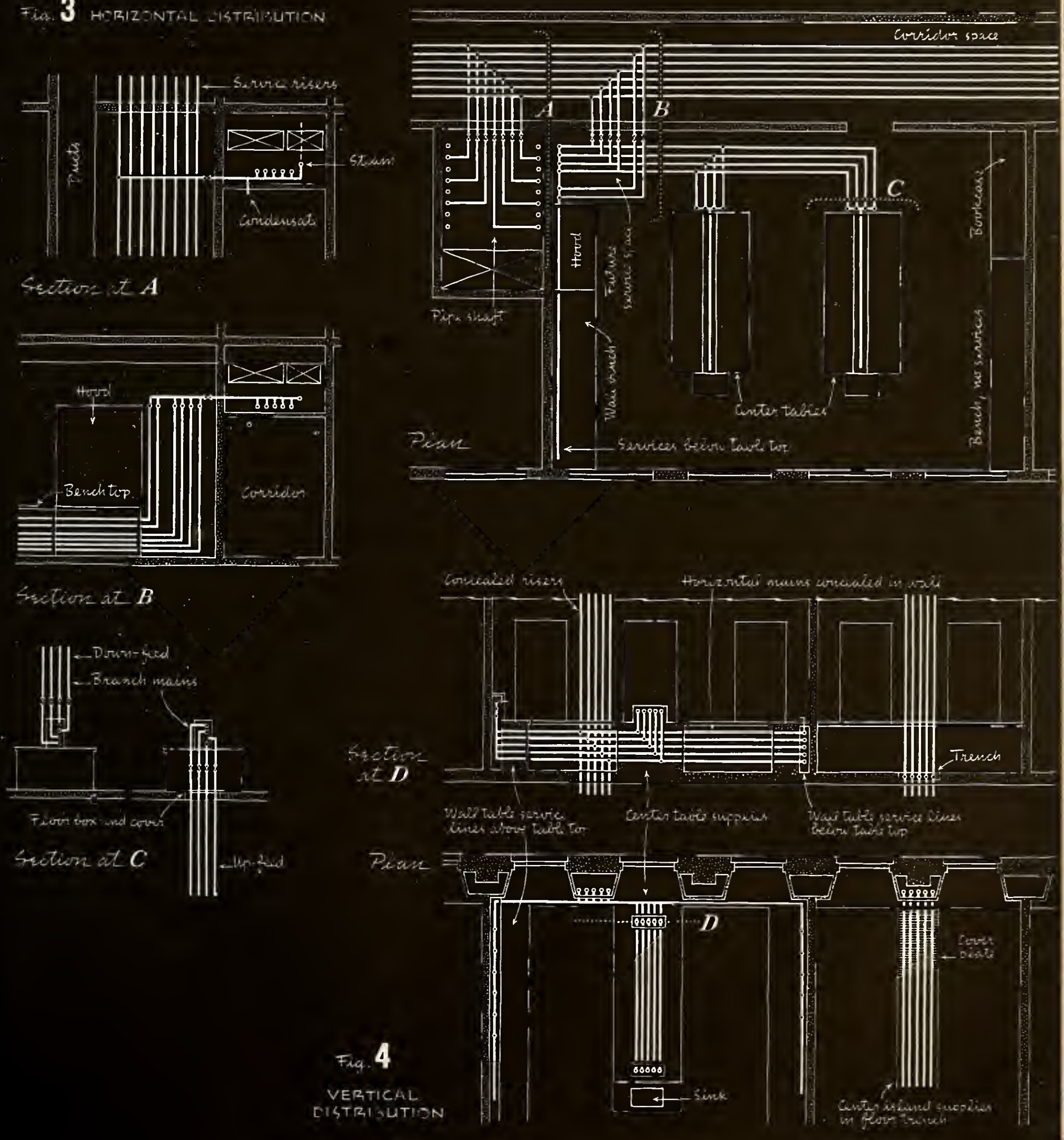


Fig. 3 HORIZONTAL DISTRIBUTION

Fig. 4 VERTICAL DISTRIBUTION

252 psi at 70 F. It is corrosive, but because the gas is normally very dry, brass pipe and fittings are satisfactory.

A single-stage regulator with a forged brass body and a steel gage with stainless steel parts should be provided.

Aluminum and hard-rubber pipe and cocks are used extensively for distribution.

waste piping

Laboratory wastes are variously constructed of cast iron, lead, chemical stoneware, high-silicon iron, synthetic-phenol-formaldehyde resin, and glass.

The use of cast-iron pipe for waste connections, especially if concealed, is not recommended where acid wastes are encountered, and should particularly be avoided when laboratories may be idle for considerable periods.

The use of lead for laboratory wastes should be confined to traps and to branch connections between outlets on laboratory furniture. Lead pipe which is used for domestic plumbing contains a small percentage of zinc and is unsatisfactory for chemical work. Chemical lead should be 99.98 percent pure and should withstand the action of strong sulphuric acid up to about 132 C. Joints should preferably be wiped or burned joints.

Chemical stoneware with bell and spigot joints provide an excellent material for concealed wastes. The joints should be made up with asbestos rope wicking impregnated with acid resisting graphite or mastic and a hot melting acid-proof calking compound.

For horizontal lines two rings of packing and a topping collar of about 30 percent ground asbestos, 20 percent talc and 50 percent silicate of soda, to keep the calking compound from running when subjected to heat, should be used.

High-silicon pipe is widely used but is expensive and brittle and care must be taken when installing and making joints to prevent damage to the pipe. Space should be left between the end of the spigot and the bottom of the hub to avoid expansion strains. Two rings of packing, as for the horizontal runs of stoneware pipe, should be used and the remaining space filled with lead.

Synthetic-phenolformaldehyde pipe has strength, toughness, and durability together with excellent corrosion resistance and may be threaded and coupled together or furnished with bell and spigot ends for which joints may be made in the same manner as for stoneware pipe.

Pyrex glass is also used in some laboratories for waste piping. Important characteristics of this glass are its very low thermal expansion and its excellent chemical stability.

traps for waste systems

Laboratory waste systems are generally connected to the sanitary sewer system, and unless the local plumbing code permits otherwise, must comply with regulations for sanitary plumbing.

As laboratory wastes are generally sterile, the use of a single trip for several outlets on a long branch, or even several items grouped together in one room, is frequently permitted.

It is not generally advisable to connect wastes from adjacent laboratories through a common trap as this makes it possible for fumes to pass between rooms which may he objectionable or even dangerous.

refrigeration

For normal requirements a direct expansion system using Freon will be satisfactory as there is no danger in case of leakage.

For very low temperature work a two-stage ammonia system may be required with the refrigerating machinery located in a separate room which is well ventilated and has direct access to out-of-doors.

Normal construction for either type of system is satisfactory.

distribution systems for laboratory services

While the present tendency is to conceal the service piping, especially in laboratories for pharmaceuticals and food products, there are many installations where for economy or ease of maintenance pipes are exposed. In such cases a poorly designed or carelessly installed system may mar the appearance of the laboratory.

For large multistory laboratories most of the services will originate on the ground floor and from there either horizontal or vertical distribution may be used.

Each has its advantages which should be carefully considered in the early stages of the design of a laboratory.

horizontal distribution

Pipe shafts extending from the ground floor to the top of the building may be suitably located for the installation of risers for service lines. These shafts should be of adequate design to permit an orderly arrangement of the risers with free access to shut off valves and for maintenance of the piping. The pipe shafts should be built in such manner that they will not create a fire hazard. Horizontal distribution mains (*Figure 3*) should be taken off near the ceiling at each floor and should be provided with shut off valves. Corridor distribution (*as shown*) is desirable, unless ceiling heights are too low to permit an orderly arrangement of duct work, lights, and piping. Ducts may be installed immediately below the ceiling, and service mains (except steam and condensate) supported on group hangers at sufficient distance below to provide space for branch duct work and piping above the mains.

Uniformly sized metal boxes with covers on each side may be installed in corridor walls for bringing services into the laboratories. The same arrangement of piping should be maintained and a shut off valve provided on each service when it enters the laboratory.

Where possible, piping should not be run over wall or center tables. Either upfeed or downfeed systems may be used for supplies to tables. Upfeed avoids vertical drops but has the disadvantage that in case of changes or repairs laboratories on two floors are affected.

vertical distribution

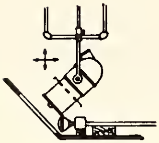
For a multistory building with a typical arrangement of rooms and equipment on each floor, a vertical system of distribution with concealed risers may advantageously be used (*Figure 4*). Removable panels may be provided for access to the risers and shut off valves. Branch connections to center tables adjacent to outside walls may be completely concealed and turrets at each end of the table may be provided with the necessary cocks for each service.

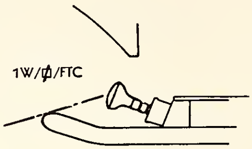
Piping to serve wall benches and hoods may be concealed below the top of the bench or may be run exposed along the partition wall. With laboratories of greater depth it may be advisable to provide risers in corridor partitions to serve equipment adjacent to these partitions.

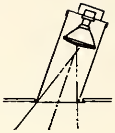
EQUIPMENT

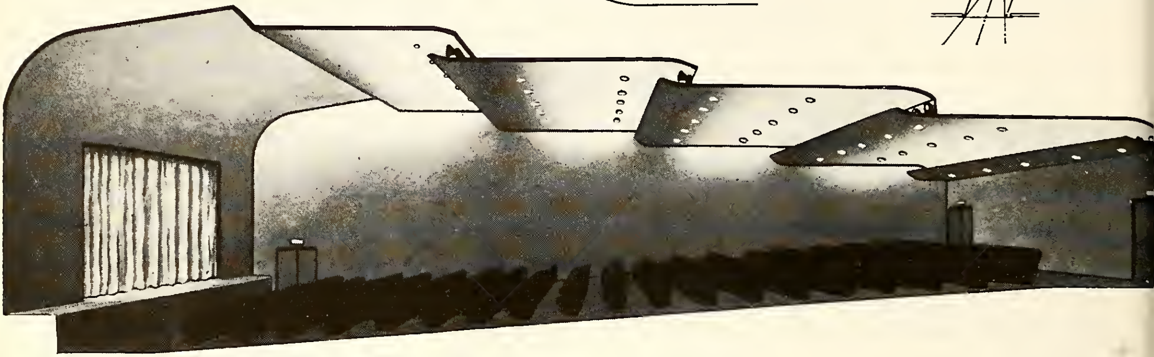
It is recognized that early collaboration between the architect and his consulting engineers—during the preliminary phase of a project—produces a much better integrated building. At this stage, the advantages of differing structural systems are considered along with the environmental control methods best suited for the location and conditions of occupancy. Even at this early date, the *type* of equipment is fairly accurately determined. An interesting illustration of this point can be found in the design of the air-conditioning systems for the Wanamaker and Gimbel department stores at the Cross County Shopping Center, Yonkers, New York. At this center, two entirely different systems were evolved by Architect Lathrop Douglass and his Mechanical Engineer, Sidney Barbanel for stores possessing identical square foot areas. These systems, of equal efficiency, were installed at identical cost. In final design, Wanamakers got a system using package units and Gimbels a central system. Wanamakers required no basement and wished a penthouse for an employees' cafeteria. Conventional use of a penthouse or basement for conditioners would have required additional construction. Wanamaker engineers recommended the use of air-conditioning package units because previous experience had been thoroughly satisfactory and also because installation costs of these units could be legally amortized over a shorter period than that of a central plant. In their experience these units had a useful life extending for quite some time beyond the amortization period. Further, repairs could be made easily and the elimination of trunk ducts offered a substantial saving in both space and expense. Because of their traditional merchandising methods, Gimbels required a "bargain basement." As a result, it was decided to put a centralized plant in the penthouse. An early suggestion of a single vertical core for delivery and return of air to the various floors was discarded in favor of two cores, one at each wall. In this manner, the Gimbel store has a central location for its escalators which commands a view of the sales areas in all directions. Thus, at the Cross County Shopping Center one finds two completely different air-conditioning systems for similar stores—requiring different *types* of equipment—resulting from preliminary design and discussion between the architect and his engineer.

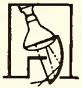
Lighting the School Auditorium and Stage

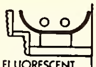

ELLIPSOIDAL
REFLECTOR LENS
SPOTLIGHTS
WITH SHUTTERS


1W/⌀/FTC


150-WATT
PAR-38
SPOT LAMP
20 TILT



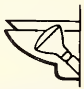

WALL OR MURAL
LIGHTING UNIT

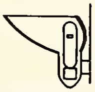

FLUORESCENT
(BLUE AND GOLD
CIRCUITS)
⅕W/⌀/FTC

Now that most schools are providing good classroom-lighting conditions, considerable attention is being directed to the specialized problem of lighting the auditorium and stage. In this article, options for lighting the school auditorium and stage are presented, analyzed, and illustrated. The equipment reviewed ranges from that suitable for the more complete installation, to that which is specifically suited to a minimum-budget installation.

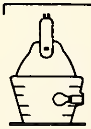
W/⌀/FTC: approximate wattage required per square-foot of floor area to produce one footcandle in service, assuming light room finishes. For specific cases, illumination level calculations should be based upon equipment manufacturer's data.

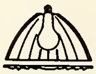
WALL URNS

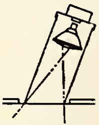

½W/⌀/FTC

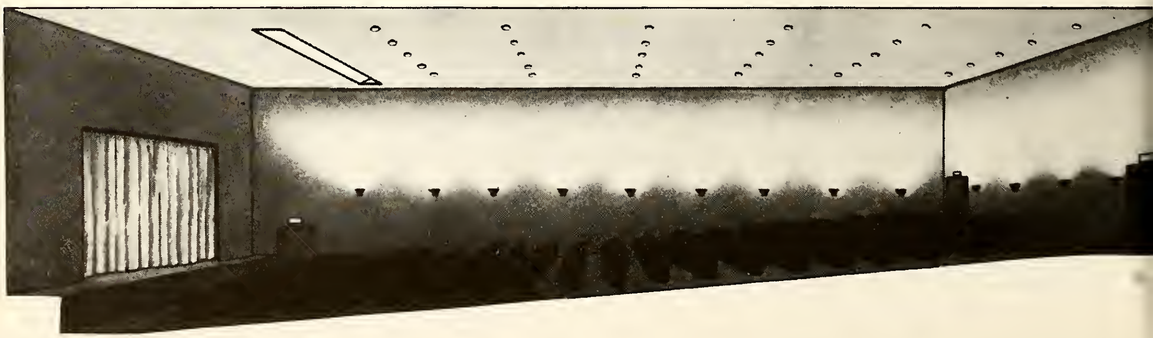

⅓W/⌀/FTC

DOWN LIGHTS


⅕W/⌀/FTC


¾W/⌀/FTC


⅕W/⌀/FTC

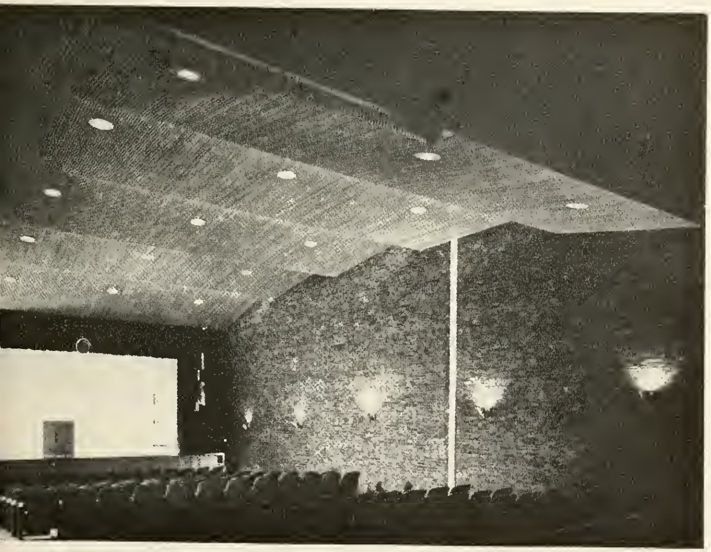


By CARL J. ALLEN*

The school auditorium is the school's, and in many cases, the community's only place of group assembly. It must serve the needs of amateur Thespians, the choral group, the school band and orchestra, and the guest speakers of the school and the community. In addition, it houses the school's educational and recreational motion picture programs. In total, there are more stage and dramatic presentations on the school stage than anywhere else in the country. The skyrocket growth of television and its needs for future stars and performers will stimulate an equal growth in student activities involving speech and dramatic training.

auditorium size

The auditorium and stage have been costly elements of a school plant in terms of capital cost per student-hour of use. The cost generally has been involved in the space required to seat the 1000 to 3000 individuals these rooms were expected to accommodate. Seating capacities of this size are being avoided, not only because of their cost but also because of the poor seeing and hearing conditions which too often result in such large auditoriums.



Above—cove lighting, downlighting, and wall lighting enhance the design of this auditorium in the Fitchburg Youth Library, Fitchburg, Massachusetts. The step-back ceiling cove provides a soft, low level of atmosphere lighting; downlights produce the major part of the illumination over the seating area; wall urns give a brightness pattern relief to the unbroken expanse of the brick wall.
Photo: Ezra Stoller©Pictor

When an individual in an audience is seated much more than 75 feet from a speaker, the details of the speaker's expression are generally lost. This is tied in with the fact that the critical angle of detail which an average individual can discern is about one minute of arc. A quarter-inch movement of eyes or lips represents one minute of visual angle at 75 feet. This appears to be a valid reason for limiting the depth of the auditorium seating to about this distance.

The width of an auditorium is indicated partly by the results of surveys which show that individuals will not voluntarily choose seats further to the side than 100° from the face of the stage opening (plan on page 90). The width is also restricted by the fact that in viewing motion pictures it is desirable to be seated within a 30° angle from the centerline of a matte screen or within 22°, in the case of a beaded screen. Outside this zone the screen brightness drops off markedly. These visual requirements tend to limit the capacity of an auditorium to less than 1000 seats—even with a balcony. Where larger assemblies are necessary a few times a year, as in the case of commencements, they frequently can be housed in the school gymnasium, where large seating capacities on folding bleachers can be provided. This leaves the auditorium to its role of being an intimate theater, where good seeing and hearing conditions can be expected.

The initial plans for nearly all schools call for an auditorium; yet the building budget frequently demands something less. The auditorium-gymnasium is one compromise. In large secondary schools, this type of dual-purpose room generally has not been completely satisfactory, because of time and usage conflicts between the major athletic and dramatic events. On the other hand, in smaller elementary schools the play-area, assembly-type room equipped with a simplified stage is reasonably successful. Flat floors naturally do not provide good seeing conditions. Folding bleachers at the rear of the room can help this situation. In some schools, the only assembly area initially provided may be the cafeteria-study hall with a raised platform at one end. Whichever type is used, proper lighting can improve the effectiveness of the room.

auditorium lighting

The lighting requirements of the auditorium may be approached in two ways. First is the need to provide general atmosphere illumination, wherein suitable brightness patterns are created to give the visual impression of a well-lighted, esthetically pleasing room. The second is to provide supplementary audience illumination: i.e., controlled light over the seating area in an amount ade-

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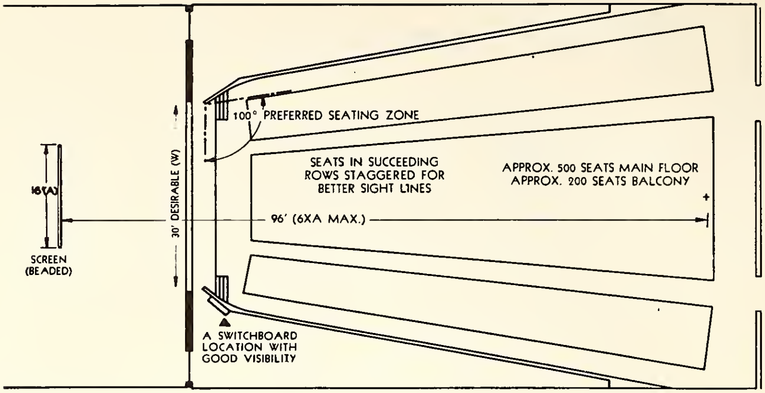
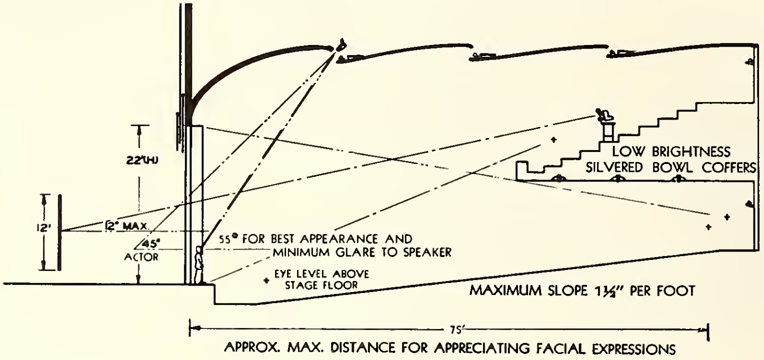
* *School Lighting Specialist, General Electric Company, Nela Park, Cleveland, Ohio.*


16'(A)
SCREEN (BEADED)
30' DESIRABLE (W)
100° PREFERRED SEATING ZONE
SEATS IN SUCCEEDING ROWS STAGGERED FOR BETTER SIGHT LINES
APPROX. 500 SEATS MAIN FLOOR
APPROX. 200 SEATS BALCONY
96' (6XA MAX.)
A SWITCHBOARD LOCATION WITH GOOD VISIBILITY


22'(H)
12'
12° MAX.
45°
ACTOR
55° FOR BEST APPEARANCE AND MINIMUM GLARE TO SPEAKER
EYE LEVEL ABOVE STAGE FLOOR
LOW BRIGHTNESS SILVERED BOWL COFFERS
MAXIMUM SLOPE 1½" PER FOOT
75'
APPROX. MAX. DISTANCE FOR APPRECIATING FACIAL EXPRESSIONS

quate for reading programs, notes, papers, etc.

Flexibility in the lighting installation is desirable. For general assemblies, or before curtain time when programs are being read and friends recognized, a level of 10 footcandles is recommended. For stage and motion-picture presentations, about half a footcandle over the audience seating area is generally sufficient. None of this light should be allowed to strike a motion-picture screen directly. If the area is to be used for study purposes, a 30-footcandle level is recommended.

As the hours of use of the school auditorium in one year are generally not sufficient to justify the installation of fluorescent light sources—and because they cannot be easily dimmed to black out—the incandescent-type light source is ordinarily used for auditorium lighting. Fluorescent lamps do have the advantage of being a slender, extended source available in a variety of efficient colors and, hence, can be used where these features are desired.

atmosphere lighting

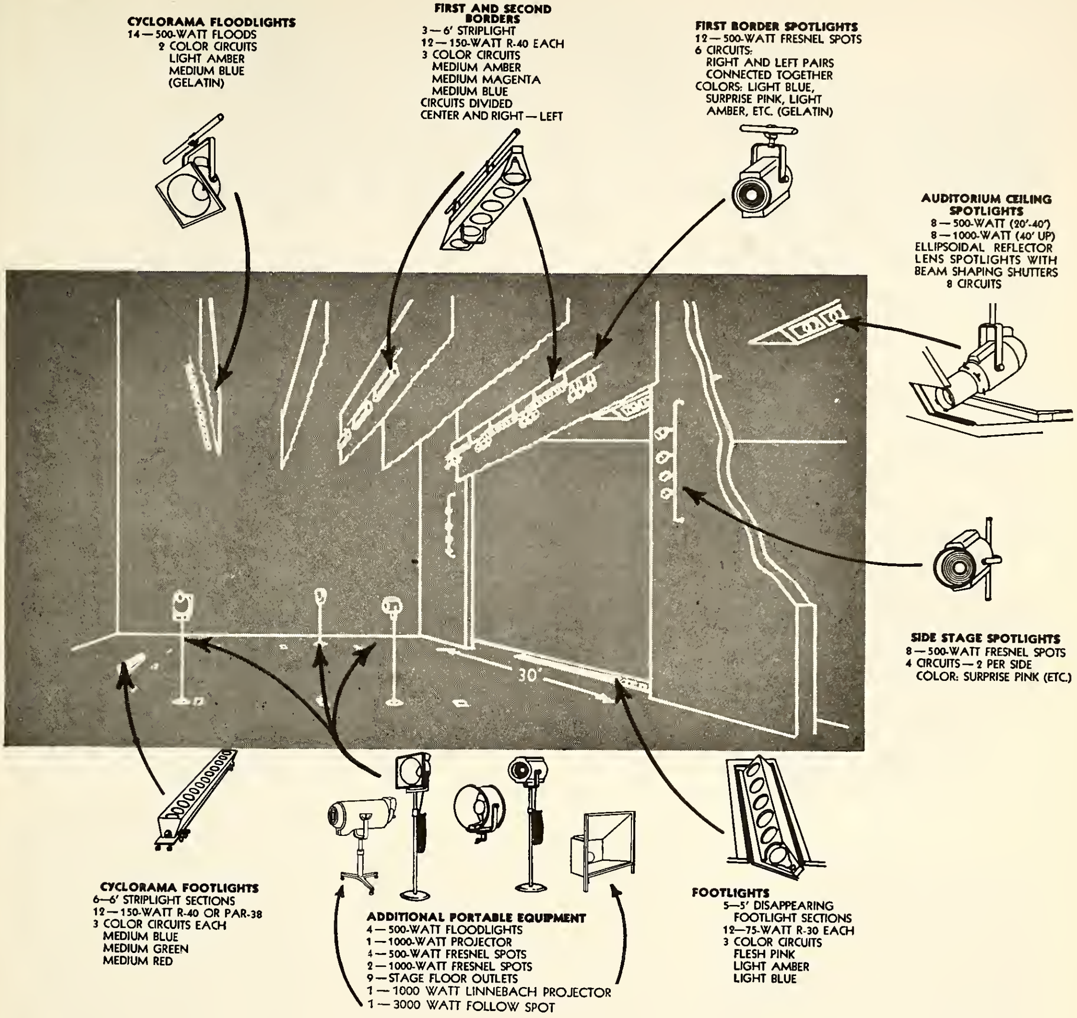
Atmosphere lighting in the auditorium may be accomplished in a variety of ways as shown (see pages 88-89). One trend is toward the use of step-back ceiling coves in which the light is directed forward, with the light sources concealed from the normal view of the audience. Color may be incorporated in these coves by using reflectors or lens units with individual lamps, or by the use of reflectorized lamps with color roundels. Various levels of illumination and mixtures can be obtained by operating the circuits on dimmer control. One possible color combination is a light-blue and light-amber circuit. With these, either a warm or cool character can be introduced; in addition, by a balanced mixture of these two, a near white can be obtained. The surfaces to which the light is directed should be light and fairly neutral in color, if a full range of color effects is desired.

Indirect lighting provided by suspended fixtures, or from wall urns or coves, can be pleasing in quality and suitable for auditorium lighting purposes. As it is generally desirable to reduce the number of suspended luminaires to a minimum in the larger auditoriums, specially designed luminaires may be used, which incorporate a number of fairly high-wattage lamps. In such equipment, or in wall units, the reflector-type lamps have been used to minimize the light depreciation, due to dust settling in the lighting equipment. Where maintenance is difficult, due to the mounting height, lowering hangers are useful. Suction-cup lamp changers on extension poles, used from moderate height step ladders can facilitate lamp replacements, when the lamps can be reached from directly below.

The area beneath the balcony may be lighted by large coffers of low brightness. Where equipment cannot be recessed in the balcony soffit, a cove located across the rear wall containing reflector lamps directed out over the underside of the balcony may be employed.

audience lighting

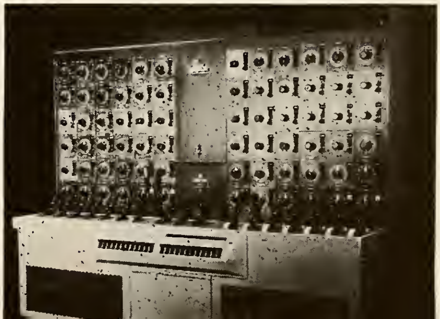
The atmosphere-lighting system may be very effective in building a pleasing brightness pattern in the auditorium, yet deliver relatively few footcandles over the seating area. The needed additional lighting over this area may be accomplished by direct lighting from large elliptical reflectors, lens plate units with opaqued risers, silvered-bowl-lamp louvered coffer units, or reflector-lamp downlights. This lighting should be so controlled in distribution that, even under darkened room conditions, a reasonable level can be produced without the audience being unduly aware of the light sources. One means of minimizing the presence of the light source is by



Above—for this stage layout, a control board with 50 12-step rotary switches, 10 5KW dimmers, six 2KW dimmers, and eight non-dim switch controls is suggested as a minimum arrangement.

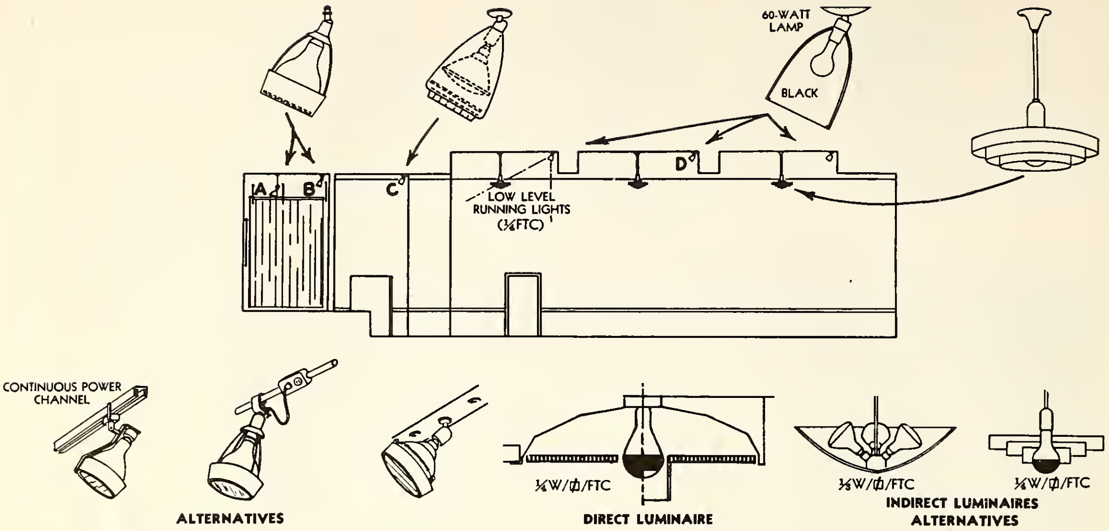
Below—within this autotransformer control board, each stage circuit terminates in a rotary switch; by this method the individual load circuits can be connected to any one of a number of dimmers, or directly to a line switch.

Photo: courtesy of Kliegl Bros.

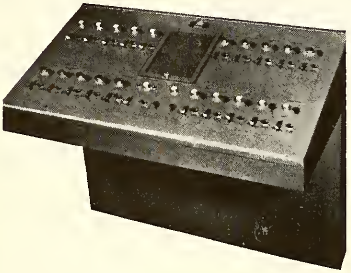


location	circuits	5 kw dimmers	2 kw dimmers
auditarium-ceiling ports (left)	4	1	
auditorium-ceiling ports (right)	4	1	
first-barder spotlights	8	2	
first borderlights	6	3	
second-borderlight batten	8		
cyclorama-floodlight batten	4	1*	1*
side-stage spotlights	4		2
floor pockets	9	2*	
footlights	3		3*
	50	10	6

* frequently available for miscellaneous use.



Above—a minimum-budget installation using reflectorized lamps. Projector and reflector lamps are available in a variety of spot and floor-beam patterns and range from 75 to 300 watts. Color filters, available in a wide assortment of hues, may be snapped into the adjustable lamp holders.



Above—miniature potentiometers in this console board control the postion of remotely located motor driven dimmers. After the dimmers have reached a given position, the potentiometers may be preset for the next cue.

Below—finger-tip operation of 12 dimming circuits is obtained with this autotransformer type control board. The plug-and-jack panel permits the circuits to be grouped together and allows this portable board to be used at several locations. Total capacity is 12,000 watts; individual circuit capacity is 2400.

Photo: courtesy of Superior Electric Co.

Photo: courtesy of Ariel Davis Manufacturing Co.

the use of narrow beams of light tilted forward from overhead units in which the source brightness is concealed from view. The tilted unit, using a 150-watt PAR-38 projector spot lamp, is an example of this type of directional lighting.

combination areas

Recessed or surface-mounted coffers, using either fluorescent lamps or silvered-bowl incandescent lamps—equipped with metal louvers which shield the brightness and also protect the lamps from accidental breakage—are possible solutions for lighting the elementary school play-area, assembly-type rooms. Some indirect lighting, for example, from protected wall urns, also is desirable. For combination areas which are primarily gymnasium, typical industrial-type fluorescent or incandescent equipment with guards offer the simplest answer.

stage lighting

The requirements of stage lighting are varied, hence the equipment and controls should permit as great a degree of flexibility as possible. A typical complement of stage-lighting equipment for a moderate-size school stage is shown (preceding page). For most school-stage purposes, the order of importance of the various kinds of stage-lighting equipment is: (1) auditorium-ceiling spotlights, (2) first-border spotlights, (3) first-border striplights, (4) intermediate-border striplights and spotlights, (5) supplementary portable equipment—spots, floods, and projectors, (6) side spotlights, (7) rear-stage cyclorama footlights and overhead floodlights, (8) footlights. Items (1), (2), (3), and (4) represent the minimum, initial equipment usually required.

AUDITORIUM-CEILING SPOTLIGHTS. These units light the speakers on the stage apron and provide the necessary frontal lighting for actors on the stage. Controlled-beam spotlights are recommended for this service. One of the most effective ways of accomplishing this is by the use of ellipsoidal reflector-lens spotlights equipped with beam-shaping shutters. With such units the beams can be confined to a specific acting area, and stray light can be kept off the proscenium arch by means of the framing shutters. Another suggestion is to use sealed-beam spot lamps in housings designed to absorb the direct, stray light. Auditorium spotlights are usually located in the auditorium ceiling so that their beams form a 45° angle with the horizontal when aimed at an actor standing slightly behind the first-border lights. For spotlighting speakers on the stage apron, the vertical angle should be about 55° to minimize the effect of glare on the speaker. Two such units, located about 60° apart horizontally, give pleasing facial shadows and, at the same time, produce minimum disturbances to the speaker. The front face of the balcony frequently provides a convenient location for spotlights. In this location they give good vertical illumination for stage presentations, but should not be used for lighting speakers, because of the high glare they produce.

First-Border Spotlights. Because of their forward locations, these spotlights can direct light from a favorable angle onto the acting areas. As the equipment is relatively close to the areas being lighted, fresnel-type spotlights are desirable because of their soft-edge beams. The trend in stage lighting is to the use of more spotlights of this type over the acting area rather than multi-rows of borderlights. An average stage is frequently divided into six acting areas —three across and two deep; each area generally is lighted from two spotlights —one from each side of the stage.

While the incandescent light source is well matched and quite flattering to the human complexion, in stage lighting it is frequently desirable to further enhance the appearance of the actors. It is general practice to light an acting area with a warm-tinted light from one direction and a cool-tinted light from an opposite direction. This simulates the pleasing and natural lighting effect produced when a person is illuminated by the warm rays of the sun and the cool light of the sky. Light scarlet, light flesh pink, and light straw color filters are commonly used for the warm effect; light steel blue and special lavender are used to produce the cool lighting effect.

Border Striplights. The purpose of these continuous strips of lighting units is to tone the set and fill in those areas not illuminated by the individual spotlights. They are usually arranged on several color circuits. Amber, magenta, and blue colors in the medium transmissions are suggested. Each color circuit needs its own dimmer control for flexibility in mixing colors. Provisions for interchanging these colors with other color filters are desirable. The secondary borderlights should be equipped with outlets for the use of additional spotlights, the same as used on the first border. Short ladder-like frameworks suspended from the ends of the border-strip battens provide means of supporting spotlights used for cross-stage lighting purposes. Lazy-tong devices, as used in television studios, are also useful in this same application. Such provisions help keep the stage floor free of spotlight stands and towers.

Supplementary Portable Equipment. The most useful auxiliary type equipment for use on the stage is the fresnel-type spotlight which can be adjusted to narrow or wide soft-edge beams. Where a broad flood of light, creating a soft shadow, is desired, the open reflector floods, with color filters or diffusing screens, are used. The brackets on these units should be such that they can be used on pipe stands or fastened to the back of stage scenery for illuminating doorways, background, scenery, etc. Where sharp-edge beams of various shapes are needed, the ellipsoidal reflector-lens spotlights are particularly useful. For illuminating backgrounds from the floor, portable striplights are used. They are similar to the border striplights, but used in an inverted position. Where it is desirable to attain the dramatic effect produced by a narrow-beam, follow spot operated from the balcony, the 300-watt incandescent spotlights may be used. Such units can produce up to 75 to 90 footcandles at 100-foot distances.

The Linnebach lantern should be included in the supplementary equipment. It is an open front, black enclosure, equipped with a concentrated light source which projects any cut-out or transparent pattern placed in front of it. This type of scenic projector gives the stage crew and the school art department valuable experience in shadow and transparency projection, and permits considerable saving in cost and time in preparing painted backdrops.

Rear-Stage Overhead Floodlights. These units may be of the border-striplight type or large reflector floods. They are generally used to light a sky-effect cyclorama or the background scenery in outdoor sets. Color is obtained by gelatin in frames which slip into the units. For good uniformity, and to minimize emphasizing any wrinkles or irregularities in the cyclorama surface, they should be placed well forward, preferably about ten feet in front of the surface to be lighted. Rough, sand-floated, white cement plaster on the rear stage wall provides a reasonably good cyclorama. Thin, theatrical scrim hung in front of such surfaces can greatly enhance the illusion of depth.

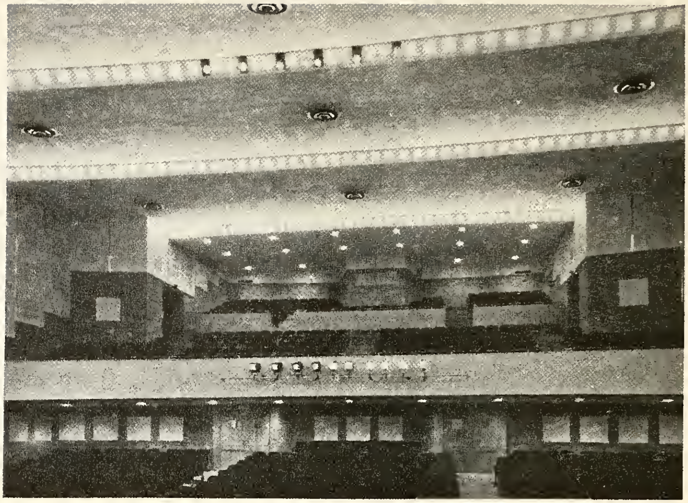
the small school stage

A minimum-budget auditorium and stage relighting installation is shown (top acrosspage). The reflector and projector lamps are employed for the stage lighting as they give a suitable degree of control, are convenient, and represent a low original cost. In suitable accessory equipment with provision for aiming and a means for holding color filters, they serve for many applications which do not require the flexibility attainable with the regular stage-lighting equipment. As many presentations on even a small elementary-school stage require beams of light whose size can be varied, a few good theatrical spotlights should also be provided.

control equipment

The goal in stage-lighting control equipment is to obtain the maximum flexibility for a given investment. One way of attaining this is through the use of autotransformer dimmers which can be selectively connected to the various stage circuits. The autotransformer will satisfactorily dim any practical load up to its rated capacity. While lower in cost, the resistance-type dimmer is generally limited to a given wattage, thus it does not permit the flexibility possible with autotransformer dimmers. The electronic and saturable-reactor type dimmers permit remote control board operation, and are ideal where their higher cost can be justified. Remote operation is also possible with motor-driven dimmers. Motor drive is valuable on house-lights circuits as the control points may be conveniently located at a number of locations such as in the projector booth,

Above and below—a well lighted rostrum is a needed accessory for any auditorium. In this rostrum, two 8-watt miniature fluorescent lamps illuminate the speaker's notes and cast a pleasing glow on his face. A silent, electric timer paces his presentation and turns on an illuminated warning when the time is exhausted. A switch card on a retracting reel permits the speaker to signal the slide operator, even if he walks away from the rostrum. In this custom-built rostrum, a motorized elevating system raises or lowers the stand to suit the speaker's height.



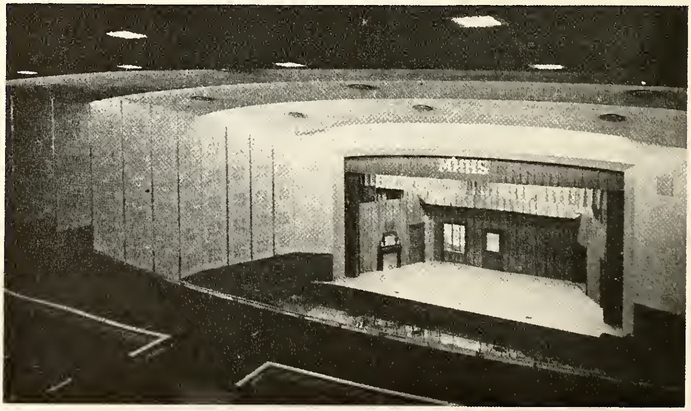
at the rear of the auditorium and on the stage at the control board.

Three general types of interconnect devices are used to obtain flexibility; they are: (1) heavy duty rotary switches, (2) flexible-cord plug-and-jack panels, and (3) cross-grid interconnect panels. The rotary switches provide easy and convenient interconnections. The plug-and-jack system is lower in cost, but not quite as convenient to operate. The cross-grid interconnect system permits maximum flexibility, but should be used only by experienced personnel, if it is not of the dead-front type. Silent-type magnetic circuit-breakers are now widely used for on-off control, and for providing the necessary overload protection for both stage circuits and dimmers.

Each control board should be provided with a drawing showing all stage circuits, interconnect facilities, and capacities of the dimmers. Unfortunately for the students, this is seldom done and an air of unnecessary mysticism frequently surrounds the board.

In considering the lighting equipment for a school stage, it is well to establish a complete master plan. Frequently all the equipment may not be obtained initially. With a definite goal in mind, the most useful equipment should be installed first and the additional equipment obtained in the order of their usefulness.

Above and below—176 100-watt lens plate units in five stepback coves provide comfortable general lighting in this high school auditorium at Maple Heights, Ohio. Dimmers are used for gradual transition. Spotlights are located in the ceiling and balcony front to furnish frontal lighting for dramatic presentations.



Control of Radiant Panel Heating

BY EDWIN F. SNYDER*

Interest in radiant panel heating has increased so tremendously since the end of the war that it has called for serious study on the part of temperature control manufacturers to provide the proper kind of comfort control with this type of heating. Because of some of the inherent features of radiant panel heating, the type of controls generally used with standard convection systems usually are not adequate with this type of system.

Radiant panel heating systems may be classified in two ways. First, by panel location such as floor, wall, ceiling, and baseboard. And secondly, by means of a heating medium such as hot water, warm air, or electricity. In some instances, these systems combine one or more of the basic types with a form of convection heating and become, in effect, split systems.

Each type, or combination of types, of radiant panel heating has its own peculiar characteristics from a control point of view, and must be handled individually. Radiant floor panels are generally considered to offer the biggest control problem and will be considered first.

Radiant floor panels are most commonly constructed by pouring a concrete slab directly on the ground with water pipes or air passages about midway in the slab. The panel is usually constructed so that there are about 2" of concrete below the pipes and 1½" to 2" above the pipes. This construction, of course, gives a large mass to the panel, and this mass is the source of most control problems. Due to the construction, floor panels are very popular, particularly in low cost housing.

The maximum surface temperature of a floor panel is normally considered to be about 85F. Discomfort is apt to begin beyond this temperature, and this limitation furnishes the second control problem with this type of heating system and is one which will be discussed in some detail.

Since outdoor temperature can usually be considered as a measure of heating load (neglecting the variables of sun, wind, and occupancy), then Figure 1 shows graphically the relationship between outdoor temperature and floor surface temperature. With 70F outside air, no heating is required and a floor surface temperature of 70F is satisfactory. At the assumed outdoor design of zero F, comfort heating must be supplied, but a floor surface temperature of 85F must not be exceeded. This means that a heating load variation represented by a span of 70F in outdoor temperature must be compensated by a heat source which is allowed to vary only through a span of 15F, thus giving a ratio between outdoor temperature change and panel surface temperature change of $\frac{70}{15}$ or 4.67:1, and this ratio becomes greater with lower outdoor design temperatures. Referring again to Figure 1, it can be seen that a 10 percent change in load or 7F change in outdoor temperature must be compensated by only a 1.5F change in floor surface temperature. And, of course, a smaller change in load must be offset by a correspondingly smaller change in floor surface temperature. As a result, the temperature controls used must respond almost instantly to a change of temperature of a small fraction of a degree to prevent the system from going into an uncontrolled "hunt."

The large mass of the average floor panel was also mentioned as presenting a control problem. This is due to the fact that the mass is directly related to the heat storage capacity of the slab and the thermal inertia of the panel. Since considerable heat is necessary to raise the temperature of one pound of concrete one degree (about 0.27 Btu per pound or 40.5 Btu per cubic foot), and since the conductivity of concrete is relatively low, it can readily be seen that a small change in heat input to the panel is very slow to manifest itself as a change in temperature of the panel surface. The thermal inertia of the structure, on the other hand, may be something entirely different from the panel so that a small change in outdoor temperature may be felt within the structure in much less time than a corresponding change in heating medium temperature would be felt on the floor surface. This would be the condition usually found with light frame construction utilizing a concrete floor panel. Figure 2 illustrates graphically what usually happens to room temperature when standard convection heating controls are used on a radiant floor panel (the temperatures shown are arbitrary and used for illustration only). When a change in outdoor temperature occurs, it is some time before the change is felt indoors and calls for a change of heat input through the control system. Then, because of the thermal inertia of the panel, previously discussed, there is more time lost before the panel surface temperature changes and begins to affect the room temperature. During this time, the room temperature is continuing to change and as a result, calls for a still larger change in heat input. This same effect then takes place in the opposite direction, and large swings in room temperature are felt until the system finally settles out. This discussion is, of course, based upon the

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*Minneapolis-Honeywell Regulator Company

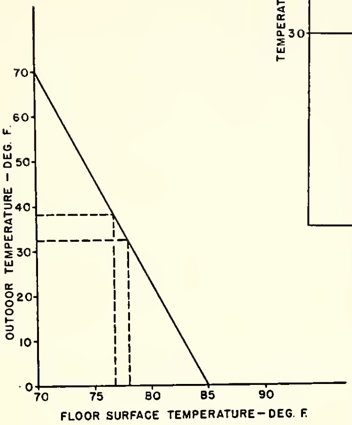


FIG. 1

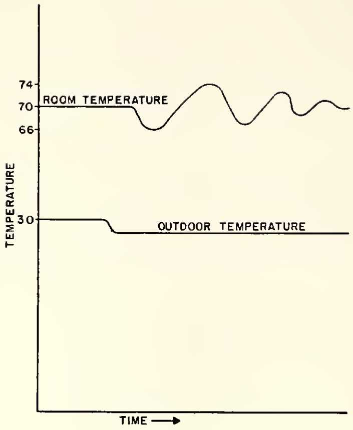


FIG. 2

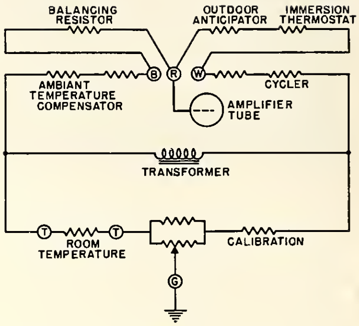


FIG. 3

use of the ordinary room thermostat with a certain mechanical differential through which it must operate.

A summation of the common radiant floor panel characteristics would include the following items:

1. High mass
2. High thermal inertia
3. Small range of surface temperature
4. Slow response to change of heat input

A control system must govern the basic heating system in such a way that in spite of any adverse conditions, the temperature of the occupied space is maintained at a comfortable level. In order to accomplish this end result with a radiant floor system, the controls must:

1. Be extremely sensitive
2. Respond almost instantaneously to load changes
3. Be simple in nature
4. Respond to outdoor temperatures
5. Furnish periodic cycling in accordance with load
6. Be service free
7. Have eye-appeal
8. Be low in cost

In order to fulfill these requirements, it is necessary to go to electronic controls and the simplest forms of this type utilize the principles of the Wheatstone Bridge. Figure 3 shows schematically a control circuit of this sort and Figure 4 a photograph of the actual controls. In Figure 4, the photograph shows the relay amplifier (1), outdoor anticipator (2), immersion thermostat (3), room thermostat (4), and cycler (5). It will be noted that the system includes only temperature sensing elements consisting of simple coils of wire which have the ability to change their electrical resistance along a relatively straight line as the temperature changes. It will also be noted that all of the temperature sensing elements are located in the same bridge circuit, and as a result, the operation of each element is interlocked with every other element to give a single end result.

The outdoor anticipator will immediately signal any change in outdoor temperature so that it is not necessary to wait for this change to be felt indoors before the heating system responds. In this way, part of the time lag in the panel is overcome by taking advantage of the time lag through the walls of the structure. The immersion thermostat, which is recommended on all floor panels, is in series with the outdoor anticipator and is located in the return line so as to measure the temperature of the water after it has passed through the radiant panel. Since these two controls are in series, they act very much like a simple indoor-outdoor control. As the resistance of the outdoor element decreases, due to a drop in outdoor temperature, the resistance of the immersion element must be increased by raising the temperature of the water in order to maintain the desired balance in the bridge circuit. In this way, the water temperature is automatically increased as the heating load is increased.

Since outdoor temperature alone does not always give a true indication of heating load, it is necessary to take into account the effects of sun, wind, cooking, and occupancy. This is accomplished through the use of the room thermostat which is located directly in the occupied space and senses the true heating load as represented by air temperature. The room thermostat has the ability to modify the action of all other controls so as to give the exact room temperature desired. This control has a sensing element whose mass is only about 1/110th that of the best bimetal type mechanical thermostat. As a result, it responds almost instantly to a change in temperature. A change of only a small fraction of one degree at the thermostat is sufficient for the con-

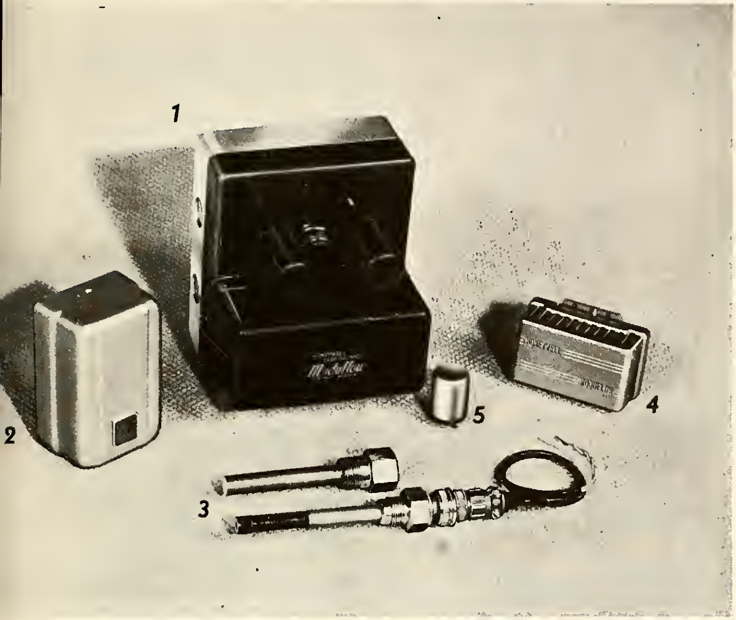


Figure 4.

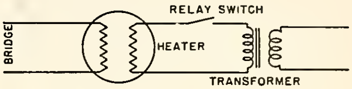


FIG 5

trol system to respond.

The cycler, as illustrated in Figure 5, consists of one winding of temperature sensitive wire and one winding that is a small resistance heater. When the switch closes and energizes the heater, the temperature rise at the bridge element tends to restore the balance in the bridge in the same manner as a rise in temperature at the thermostat or the outdoor anticipator. Since the heater is only energized when there is an operation of the heating system, it can be seen that the cycler will assist in balancing the bridge and, also, in cooling down, assist in unbalancing it and thus anticipate the requirements of the occupied space.

The cycler action is modified by the action of the outdoor anticipator, the room thermostat, and the immersion thermostat in order to set up a cycling rate that will give just the right amount of heat to maintain an even temperature. This cycling action will continue at the same rate just so long as there is no change in condition at one of the sensing elements. The moment such a change occurs, the cycling rate is changed to meet the new requirements.

Because of the action described, the fluctuation in heating medium temperature is held to a minimum for any given condition and, as a result, over-shooting in room temperature is eliminated, and the time lag in picking up panel temperature when heat is required is reduced to a minimum.

The relay amplifier serves as a nerve center for all of the external electronic controls. It receives all the minute signals, amplifies them to the proper strength, and controls the heat source accordingly.

The controls for radiant ceiling panels are basically the same as those just described. They differ only in two respects. Since ceiling panels generally are constructed of coils or ducts for water or air and with just a thin layer of plaster over the coils, they do not have the high mass and high thermal inertia of the typical floor panel. As a result, the time lag through the panel is quite small, and a clock type room thermostat may be used; thus, all of the advantages of lowered night temperatures may be realized. Also, due to the high degree of sensitivity found in the electronic controls and the relatively rapid response of this type of panel, it is not necessary to use the immersion thermostat that is used with the floor panel.

The application of these controls is as simple as the controls themselves and offer very few problems. The various applications considered are listed here and will be discussed in detail later:

Radiant Floor Panel:
  Forced Hot Water
    Single zone with domestic hot water
    Single zone without domestic hot water
    Multiple zone with domestic hot water
    Multiple zone without domestic hot water
  Forced Warm Air
    Single zone
    Multiple zone
Radiant Ceiling Panel
  Forced Hot Water
    Single zone with domestic hot water
    Single zone without domestic hot water
    Multiple zone with domestic hot water
    Multiple zone without domestic hot water
  Forced Warm Air
    Single zone
    Multiple zone
  Electric
    Single zone
    Multiple zone

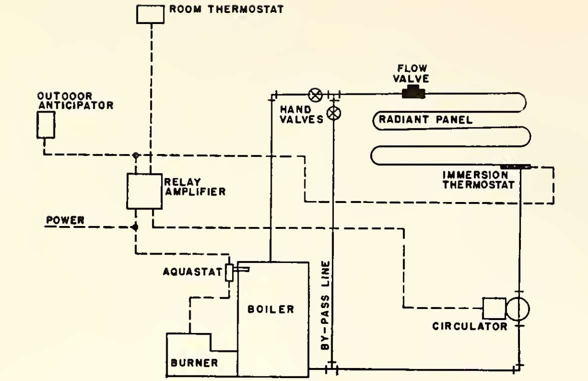
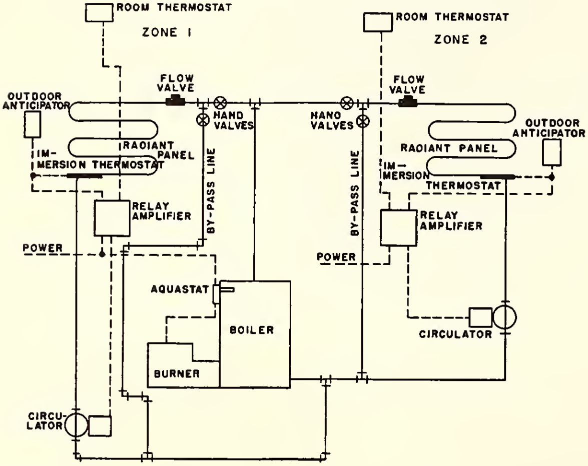


FIG. 6



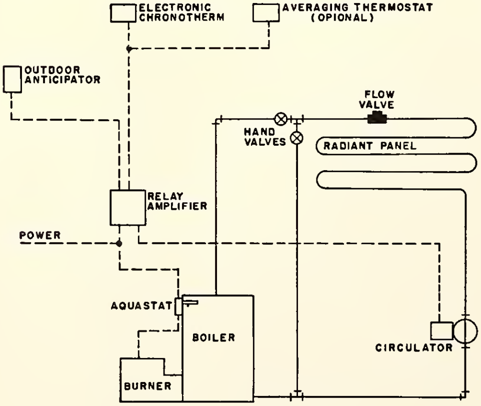


FIG. 8

Figure 6 illustrates schematically the application of these electronic controls to a radiant floor panel, forced hot water with domestic hot water. It will be noticed that the problem of furnishing high boiler water temperatures for domestic hot water and relatively low water temperatures for the panel is handled in an extremely simple manner. The by-pass line and the two handset valves in the by-pass and boiler lines take the place of the costly three-way mixing valve that was generally used in the past to reduce water temperatures to meet panel requirements. With the circulator in operation, these valves can be adjusted so that the temperature of the water entering the panel does not exceed the design value under outside design temperature conditions. The burner is under control of an aquastat which is set to maintain the boiler water temperature at the level required for domestic hot water demands. The electronic controls cycle the circulator so that the mean water temperature in the panel is just sufficient to meet the heating load requirements.

The application to a forced hot water radiant floor panel without domestic hot water is not shown since it is only necessary to modify the application shown in Figure 6 slightly. Since domestic hot water is not being furnished by the heating boiler, the by-pass line and hand valves may be eliminated. The aquastat is still used to control the burner, but it is set in this case for just slightly above the panel design temperature.

Figure 7 is a schematic diagram that illustrates the application to a multiple zone forced hot water radiant floor panel system, in which the heating boiler also furnishes the domestic hot water. It will be noted that the same system used for the single zone application is duplicated here for each zone. This method of control is ideally suited to the problems faced in many of the large rambling one-level style homes so popular today. Modern style demands, among other things, large window areas in the home, and these areas are frequently located on the sunny sides of the structure. Since window glass of the popular types transmits solar heat very rapidly, it is possible to change the heating load in one part of the home almost 100 percent in a matter of minutes while the load on the balance of the building remains unchanged. The same condition is found in a living room or den when an open fireplace is used, or in a game room with several tables of bridge. The heating loads found in these rooms are not at all typical of those in the rest of the home. It is highly desirable to keep work areas such as the laundry or kitchen at a lower temperature than the other areas when there is little physical activity. Another factor to consider and to make multiple zoning desirable is the different floor coverings used. A single structure may have floors ranging from bare concrete to fully carpeted floors. Since carpeting, rugs, and similar materials act as insulators, it is necessary to carry higher panel temperatures in these areas in order to maintain comfortable air temperatures.

The by-pass lines and valves in each zone allow the installer to adjust for the maximum panel temperature necessary to meet all the conditions found in each particular zone. The control system then operates the circulator for its own zone along the proper cycle timing to maintain the temperature desired. Due to the sensitivity and extremely rapid response of electronic controls, there is no time lost waiting for a change in load to be reflected in interior temperature changes.

Forced hot water radiant ceiling panels, as discussed before, do not offer quite all of the problems found in the floor types. The primary differences, as indicated in the schematic diagrams, Figures 8 and 9, and in the photograph in Figure 10, are the use of a clock-type thermostat and the absence of the immersion thermostat. Figure 10 shows the relay amplifier (1), outdoor anticipator (2), electronic chronotherm (3), cycler (4), and averaging thermostat (5). The use of the averaging thermostat is optional. In this application there are several possible ways to control the burner and circulator, but it is still recommended that the electronic controls cycle the circulator, and the burner be controlled by an aquastat. In this way advantage is taken of the more rapid heat transfer rate. No attempt has been made to show schematic diagrams of the systems without domestic hot water since they would be so similar to those shown for the floor panels.

Single zone radiant panels utilizing warm air as the heating medium may be handled with exactly the same controls used with their counterparts in the forced hot water panels. The only difference would be that with the warm air panels, the blower is run continuously under control of a conventional

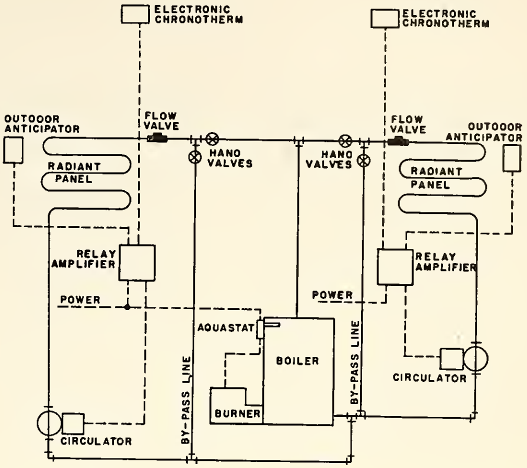
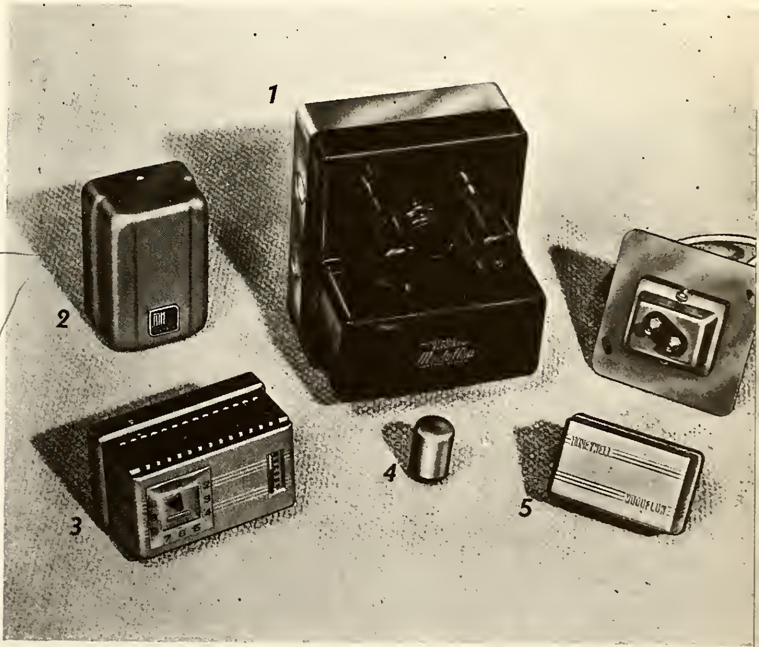


FIG. 9

Figure 10.



fan control and the electronic controls are used to cycle the burner itself. This change is made necessary by the relatively small amount of heat contained in air, compared to that contained in an equal weight of water at the same temperature. The enthalpy of dry air in Btu per pound at 105F is given as 25.232 and at 70F as 16.816 or a release of 8.416 Btu per pound. The enthalpy of water at 105F is given as 73.04 and at 70F as 38.11 or a release of 34.93 Btu per pound of water. From these figures, it can be seen that one pound of water will release about four times as much heat as one pound of air over the temperature range found in a radiant floor panel. Figure 11 shows schematically the application of electronic controls on this type of heating system.

Multiple zone control of a forced warm air radiant panel is handled in a manner very similar to that used on forced hot water. In this application, as shown in Figure 12, the burner is controlled by an outdoor reset controller which automatically raises the temperature in the plenum temperature as the outdoor temperature falls and lowers it as the outdoor temperature rises. The control operates along a prearranged program so that the temperature of the heating medium is always roughly commensurate with the heating load. The final control of the space temperature is controlled by a modulating type room thermostat which governs the position of volume dampers in each zone main duct so that the volume of air entering each zone is modulated to just offset the heating load. Normally, the outdoor reset controller is set to give slightly higher temperatures than normally desired, and the zone dampers then reduce the heat input to meet actual demands.

Electric panel heating is becoming increasingly popular and usually consists of panels with a low mass and low thermal inertia. It is extremely flexible in application and lends itself very readily to multiple zone or individual room control. The primary control is a fast cycling room thermostat that controls the pilot side of a load relay. The rapid cycling thermostat gives a very narrow fluctuation in panel surface temperature at the desired level. As the load changes, the mean surface temperature is changed appropriately to meet the new load demands. Figure 13 shows a simple circuit diagram for this type of control.

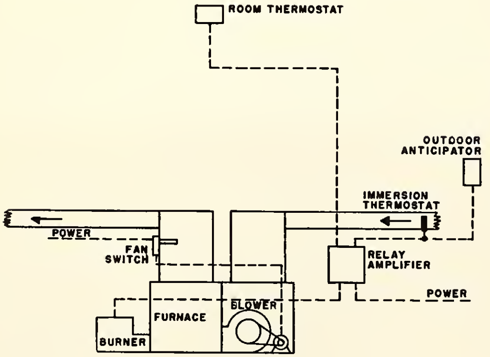


FIG. 11

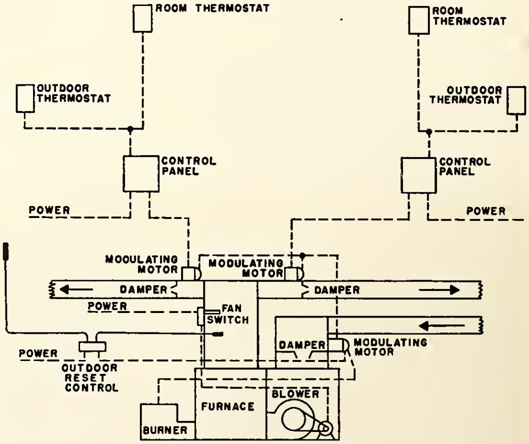


FIG. 12

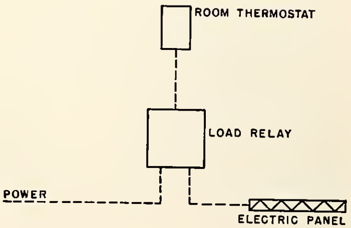


FIG. 13

Heat Pump Data

BY ROBERT H. EMERICK

Approx. Cabinet Dimensions, Air-Source Units

Standard size, horsepower	Over-all width, inches	Over-all depth, inches	Over-all height, inches	Weight pounds
3	62	48	74	1930
5	78	54	74	2890
7½	90	66	80	3880
10	99	76½	83	4750

Approx. Cabinet Dimensions, Water-Source Units

Standard size, horsepower	Over-all width, inches	Over-all depth, inches	Over-all height, inches	Weight pounds
3	70	58	69½	1288
5	70	58	69½	1691
7½	83	61½	76	1809
10	99	79½	80½	2800

Heat Production, Air-Source Units

Standard size, horsepower	Heat produced, Btu per hour, various air temps. 20 F	30 F	40 F
3	30,400	33,400	36,700
5	50,600	55,500	61,000
7½	75,000	83,300	91,500
10	101,000	111,000	122,000

Heat Production, Water-Source Units

Standard size, horsepower	Heat produced, Btu per hour based on 50 F water	Water required* gpm
3	48,000	16
5	80,000	20
7½	110,000	25
10	160,000	25

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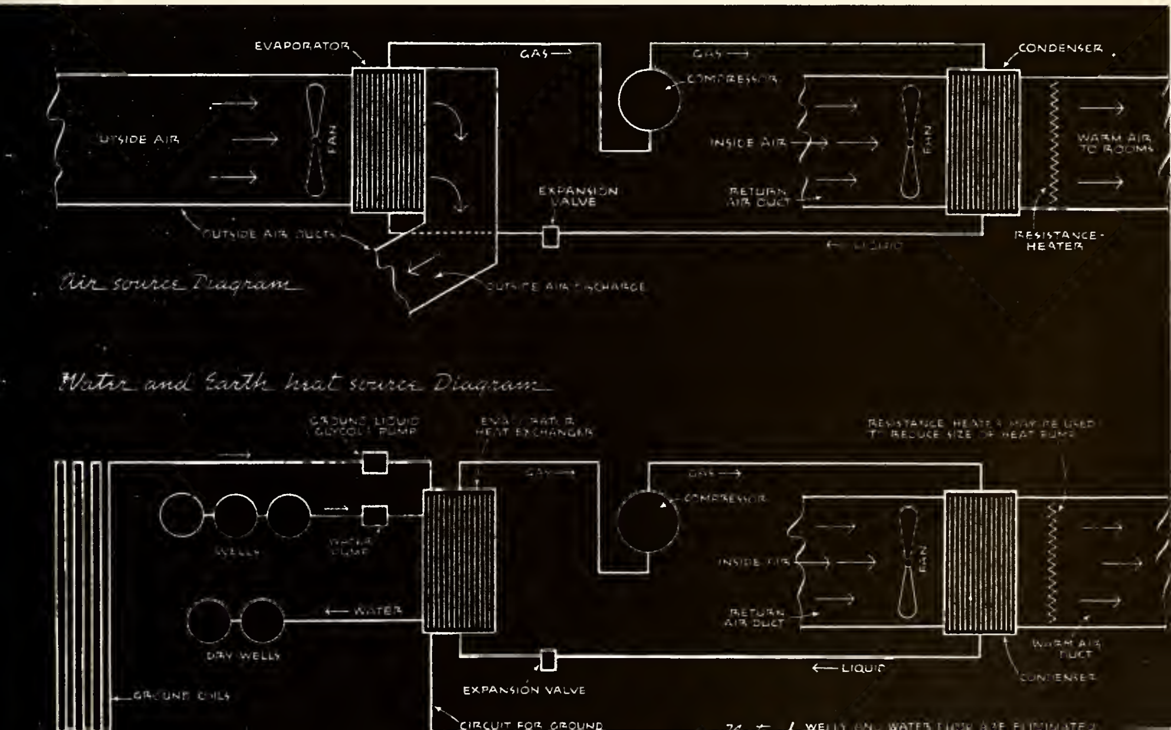
* Less water is needed if temperature of water is higher than 50 F; more water, if temperature is lower.



Power-Distributing Systems for Commercial Buildings

BY H. H. WATSON *

From the very beginning of the electrical industry, copper has been the universally used metal for carrying current. Today the world's supply of copper seems no longer to be adequate for all of the many uses for which it is best suited. For electrical purposes, aluminum, for which there is a potentially adequate source, will be used in considerable volume in the next year. For a given application, an aluminum conductor will be larger than the equivalent copper conductor, will weigh less, will require more insulation because it is larger in diameter, may cost less, will require changes in the terminal arrangements on electrical equipment, and will most certainly require new techniques in installation. What is most important is that a shortage in copper, or even difficulty in obtaining sufficient aluminum, should not be accepted as a valid reason for a reduction in the capacity of the wiring system in a commercial building.

There is an acute temptation, in this period of material stringencies and rising costs, to initiate any discussion of the electrical system of a building with a promise of cost reductions and materials savings. Realistically, the electrical engineer is faced with the problem of providing increased amounts of electrical energy for the higher levels of illumination and the increased use of air conditioning which now prevails. The electrical engineer further takes a dim view of any cutback in the dimensions or quality of his design, because most of the economies to be made by close attention to detail have long since been factored out by the accuracy which is possible in electric circuit design. The lowest costs will accrue from an intelligent use of the particular material best suited to the application.

Whether the commercial building is a 40′ x 110′ "taxpayer" or a 400′ x 200′ twenty-story office building, the property is almost invariably served by a set of power lines from the utility system. After proper handling by appropriate service entrance equipment and provision for metering, the power is distributed over a system which ranges from a few branch circuits out of a panelboard to a complicated arrangement of transformers, feeders, sub-feeders, panelboards, and branch circuits with all the necessary protection and switching equipment. *(Figure 1 shows in diagrammatic fashion the basic elements of a normal distribution system in an average building.)*

In the early days of electrical wiring, insulated copper conductors were often fished through iron water pipe instead of being supported on insulators. The result has been that the traditional method of wiring commercial buildings uses insulated wire pulled into rigid conduit. The present American Standards Association standards for rigid conduit is still not far removed dimensionally from conventional iron water pipes.

Rigid steel conduit is the standard wiring method to which all other methods are compared; it is universal in its application and can be installed for all electrical uses in commercial buildings. The National Electrical Code and all codes and ordinances derived from the National Electrical Code either permit or require the use of rigid conduit in commercial buildings. There are only a few infrequently encountered applications in such buildings where rigid steel conduit is not acceptable. The standard finish for such conduit is a corrosion-resistant coat of metallic zinc applied by hot-dip galvanizing, sherardizing, or electro-galvanizing. It is permissible, however, for dry interior installations to use enameled conduit.

Because rigid steel conduit is so universally acceptable, fittings and accessories are available for any conceivable installation condition. Long usage and production in great volume have brought about a high degree of standardization. The interchangeability of materials produced and widely stocked by various manufacturers is so complete that problems of special material are practically nonexistent. This high degree of standardization and the broad field of application provide further advantages when problems of repair, rearrangement, or addition are encountered. Further, a liberal use of rigid conduit as an accessory to the other systems described later will result in definite economies.

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* *Commercial Engineer, General Electric Company, Bridgeport, Conn.*

The conditions of installation and of subsequent use of conduit, however, are frequently somewhat less severe than the maxima which rigid conduit can withstand. For these less severe conditions, the National Electrical Code recognizes electrical metallic tubing which has the inside diameter of rigid conduit but has thinner walls. Electrical metallic tubing (EMT) in sizes larger than 2″ diameter or with an outer finish of enamel is not recognized by the Underwriters' Laboratories. In general, except as restricted by local ordinance, EMT can be used in place of rigid steel conduit for both exposed and concealed wiring in commercial buildings. In this connection, it is important to note the requirement of the National Electrical Code which does not permit the use of EMT when it is exposed to mechanical injury during installation. This restriction is important and is the controlling factor in many types of construction.

Obviously, the location and number of electrical outlets required by occupants of commercial buildings are not fixed. These requirements vary from the frequent relocations of equipment in retail stores to the occasional alterations encountered in rentable office space. Less frequent are changes in the public spaces in banks and in public buildings. However, no matter how infrequently changes may be required, the problem of installing new circuits or outlets in fire-resistant construction is costly and time-consuming. Under the general National Electrical Code classification "Underfloor Raceways," several duct wiring systems have been designed for installation under the floor level. These systems have mechanical protection equal to that provided by conduit but, in addition, provide very simple means of moving, adding, and removing outlets throughout the floor area. Another advantage is the relatively large number of circuits that may be accommodated.

Underfloor raceways are made up of the duct or raceway, the junction boxes, the outlets specially designed for the system, and the necessary hardware and fittings. The duct may be made of fiber or steel and is approximately oval in cross-section. Lengths of duct terminate in junction boxes to which access is gained through a hand-hole flush with the floor surface. The ducts are installed, generally, in a network arrangement so that a duct will run under each location where an electrical outlet is desired or where it is contemplated an outlet may be needed in the future. Outlets, when placed at the time of duct installation, are supported by inserts which provide access into the duct. Wherever an outlet is to be installed later, a flush floor fitting is provided which can be replaced by an outlet; conversely, an unwanted outlet can be abandoned by removing it and substituting a flush floor plate. Further, special boring and threading tools make possible the installation of outlets in the duct at points not previously prepared. These tools are used for cutting an appropriate hole in the duct and for inserting a fitting to receive the outlet. A variety of outlets is provided for 120-volt power and for telephone and signal systems. Parallel runs of the duct systems are frequently installed for the segregation of power circuits from communication circuits. *(Figure 3 shows such a system in the United Nations Secretariat*

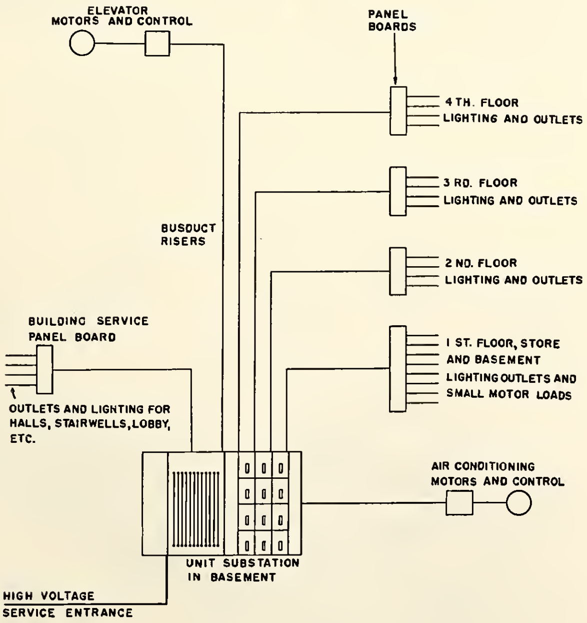

ELEVATOR
MOTORS AND CONTROL
PANEL BOARDS
4 TH. FLOOR LIGHTING AND OUTLETS
3 RD. FLOOR LIGHTING AND OUTLETS
BUSDUCT RISERS
2 ND. FLOOR LIGHTING AND OUTLETS
BUILDING SERVICE PANEL BOARD
1 ST. FLOOR, STORE AND BASEMENT LIGHTING OUTLETS AND SMALL MOTOR LOADS
OUTLETS AND LIGHTING FOR HALLS, STAIRWELLS, LOBBY, ETC.
AIR CONDITIONING MOTORS AND CONTROL
UNIT SUBSTATION IN BASEMENT
HIGH VOLTAGE SERVICE ENTRANCE

Figure 1—schematic circuit diagram for a distribution system in a store and office building.

Building before the concrete floor was poured.) The great advantage of an underfloor duct system is the ease of changing or adding outlets. This system is not limited in its use to supplying power to outlets in the floor. Such a system can also be used to supply circuits located in walls and even in movable partitions.

The use of the individual cells of cellular-metal floors as the enclosures for the electric circuits is one of the many outstanding advantages to be obtained by the use of this type of floor. *(Figure 2 shows an installation of wiring in a cellular metal floor.)* In essence, this system is an adaptation of the underfloor duct principle in which a header duct is installed at right angles to the axis of the cells and serves as a raceway to supply the circuits in the cells. This system provides complete flexibility to the electrical installation and has the added advantage that it can be used for supplying the lighting circuits in the ceiling of the floor below. Just as in the underfloor duct system, the electrical components of the cellular-metal floor system are standardized and complete installations can be made from standard components.

Busways are another type of distribution system used extensively in commercial buildings. Busway systems essentially consist of 2, 3, 4, or 5 copper bus bars contained in a sheet or ventilated steel or aluminum housing. They are generally furnished in standard 10-foot lengths with shorter sections, elbows, tees, crosses, and other fittings available to suit the specific application. The various elements are all prefabricated and are bolted together on the job to form the complete installation. A number of types of busways are available for use as feeders from transformer banks to main service switches, as distribution feeders, and as branch circuits to the individual power-consuming device. From an installed-cost standpoint, a busway system is comparable to a conduit and wire system. The labor component of a busway installation is considerably less than that of a conduit and wire system; busway elements are practically 100 percent re-usable. Thus, when changing conditions require rearrangement, the busway system shows important economies.

There are two forms of "feeder type" busway systems designed essentially to transmit power rather than to distribute it—a low reactance system and a high reactance system. The low reactance system is used where low voltage drop and resistance to high short-circuit stresses are important. The high reactance type has limited applications to short runs, or where voltage drop is not a design consideration. In both of the feeder-type systems, cable tap boxes may be installed at the points between sections for intermediate taps along the run. *(A low reactance feeder-type busway is shown in Figure 4.)*

Another type of busway is the plug-in type, available in ratings from 225 to 1000 amperes. This system is fitted with openings every 12 inches along the run. Fusible plugs, plug-in fusible switches, and plug-in circuit breakers, in ratings of from 30 to 600 amperes, are made for insertion in the bus system as protective tap-offs to feed motors, panelboards, or other equipment. Although widely used for these purposes in the industrial field to feed production lines, many other applications are found as risers in commercial buildings, or to feed groups of motors such as are installed for air-conditioning systems. *(Figure 5 shows a plug-in type busway acting as a riser in a department store.)*

In the branch circuit field there is also available a plug-in busway system rated at 50 amperes, in 2, 3, and 4-pole construction. This system has a continuous

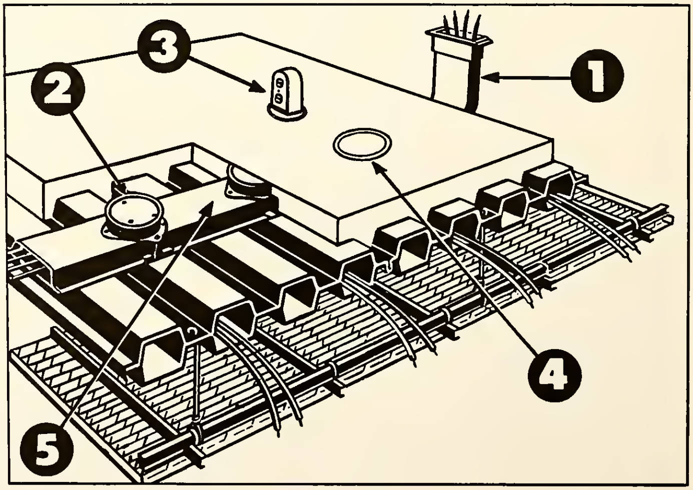


Figure 2—cutaway of cellular metal floor showing addition of electrical system:
1. *Vertical ell to extend the header to panel or cabinet.*
2. *Junction unit where the wires make a turn from the header into the floor cell.*
3. *Floor outlet for electrical service; placed where desired.*
4. *Floor covering adapter.*
5. *Standard header duct.*

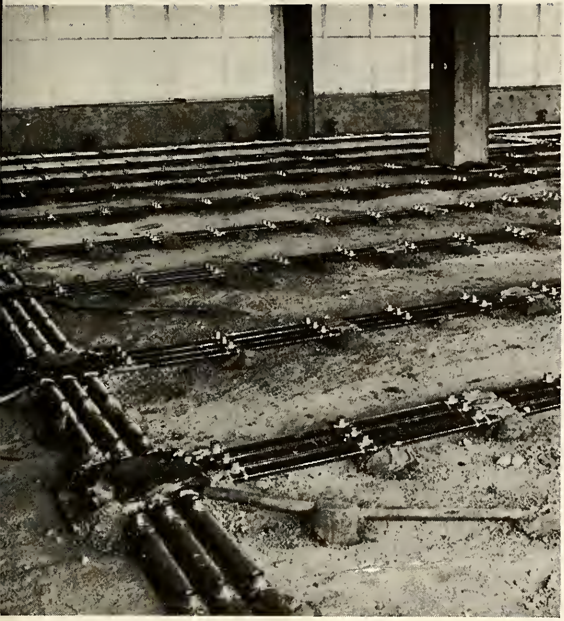


Figure 3—underfloor duct wiring system in United Nations Secretariat Building.

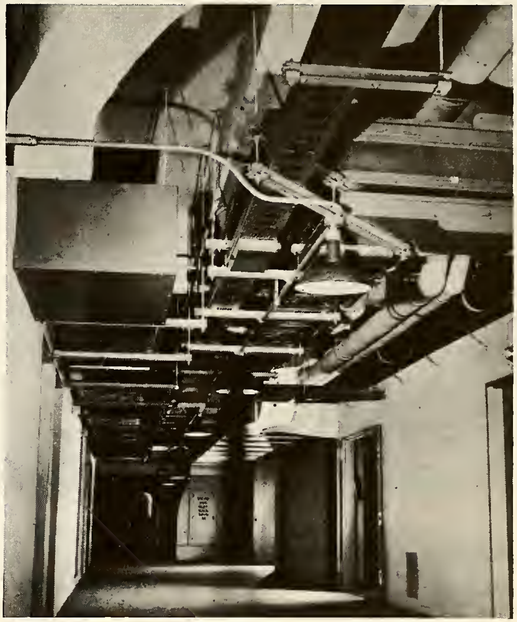


Figure 4—feeder-type busway distribution system in United Nations Secretariat Building.

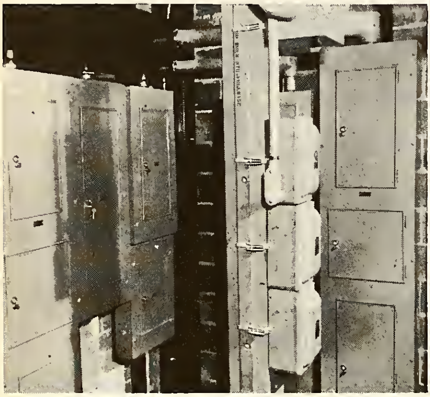
slot along the housing into which may be inserted plugs of various types to feed lighting fixtures, small motors, or appliances. Trolleys are also available for insertion in this system to feed various portable loads. This arrangement has been used quite extensively in department stores to provide flexibility for lighting systems, and in offices and industrial plants as an economical branch circuit layout. The 3- and 4-pole construction provides wide flexibility for obtaining balanced circuit loading and switching control of various fixture groups, such as is required for night lighting or emergency lighting systems.

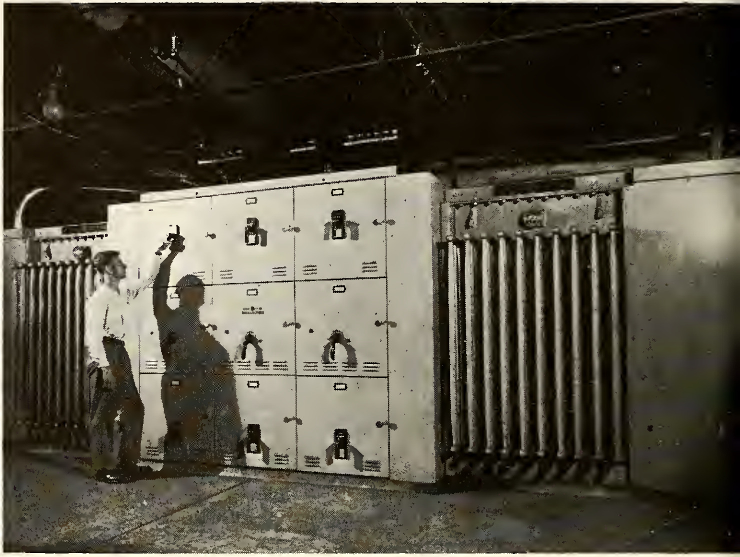
Any article on wiring materials would be incomplete without reference to factory-fabricated cable assemblies, such as armored cable, nonmetallic sheathed cable, and high-voltage interlocked armor cable. These materials consist of the insulated conductors and the associated mechanical housing assembled in the factory ready to be installed as received on the job. They are acceptable only to a limited extent in concealed work and frequently are not permitted by local codes in certain classes of buildings. The major advantage of these types of cable systems is that no detailed dimensional electrical layout is needed and installation is made by random location of the material, taking advantage of its flexibility when obstructions are encountered. Cable systems are generally lower in first cost and, where they are exposed after installation, the cost of repair or rearrangement is very economical.

Rubber for many years was the standard material for insulating the low voltage wires used in distribution in buildings. To a considerable extent, thermoplastic insulation is replacing rubber. However, there is now available an improved higher temperature rubber insulation known as Type RH; on larger sizes of wire, it permits higher current densities. Hence, both smaller cross-section of copper and lower cost of wire for a given load are possible. Still greater savings can be made by the use of Type AVA wire, in which the insulation is asbestos and varnished cambric. Because this type of insulation can withstand much higher temperatures, current densities can be so increased that a cost reduction of as much as 40 percent is possible. The reduction in conduit size adds largely to the reduced costs. In selecting these smaller diameter wires to run at higher temperature, care has to be taken that the voltage drop (or loss in electrical pressure due to resistance) is not excessive. Many well-engineered wiring systems use regular Type R wire because the limiting factor is not current-carrying capacity but voltage drop. In this instance the use of a premium grade of insulation may not be required except where long life of the insulation may be a factor.

Associated with each of the wiring systems that have been discussed is an assortment of fittings and boxes which serve to give mechanical support and provide an

Figure 5—plug-in type busway acting as riser in a department store (below). *Plugs feed the panel-boards.*





enclosure for the splices and terminations of the conductors. These accessories are well standardized. The National Electrical Code and the Standards of Underwriters' Laboratories, Inc. cover this material so accurately that there is little option as to what particular box or fitting is to be used for any particular purpose. The tendency of the architect or contractor to specify the minimum size of junction box or outlet box may result in minor savings in material, but the cost of conduit boxes of adequate size will be recovered many times over in subsequent maintenance expense.

Among the newer practices in distribution systems, the use of unit substations offers economies that cannot be neglected in any layout. The unit substation is essentially a "package" incorporating the service entrance equipment, the transformers, and the feeder switching and protective devices. These substations are designed for location in the building but not necessarily in separate enclosures, and are located as nearly as possible to the "algebraic" center of the load.

The high-voltage supply from the utility lines can be carried to the substation in interlocked armor cable and distributed from the substation over any other system or combinations of the systems described previously. The savings are principally in the material and labor of installation of the feeders and branch circuits. Likewise, there is a saving in power losses and voltage drop because the secondary circuits are shorter. Since it is self-contained, the unit substation can frequently be located in space that is of little value, even on the roof. In the unit substation there is proper coordination of the overcurrent protective devices so as to maintain a maximum continuity of service under fault conditions. This is an invaluable advantage in large stores where even minor outages of lighting result in serious shoplifting. *(A typical unit substation is shown in Figure 6.)*

The high levels of illumination now being demanded in commercial buildings, coupled with air-conditioning loads, has raised the power requirements for these buildings up to levels previously encountered only in industry. Up to now, commercial building lighting has been supplied largely from 230/115-volt, 3-wire grounded neutral, single-phase feeder circuits or, where the utility furnished power from a network system, from a 208Y/120-volt, 3-phase, 4-wire supply. The use of incandescent lamps, which shows the best over-all economy when designed for 110-120 volts, is the basic reason for these voltage levels remaining as they are. While the intrinsic economies of higher voltage have long been recognized by engineers, any move to adopt higher voltages has been hindered by lack of appropriate light sources for operation at increased potentials, by considerations of safety, and by the fact that, generally, the power supply in commercial areas has not been available at the higher voltage levels.

The introduction of fluorescent lamps in 1939 did much to change previous lighting practices. The fluorescent lamp requires a ballast between the lamp and its power supply. This ballast can be built to operate on any voltage, including values higher than the 120 volts ordinarily used for lighting. During World War II, a large amount of aircraft manufacturing area was lighted by fluorescent fixtures equipped with ballasts rated at 265 volts, so that they could be connected directly to the 480Y/277, 3-phase, 4-wire distribution system which supplied power for machinery. Large numbers of fixtures in these lighting systems were controlled by magnetic motor controllers from industrial type push-button stations.

Modern commercial buildings and, more particularly, office buildings with their large electrical requirements for elevators, fire-pumps, air conditioning, and sanitary systems, have heretofore been unable to take advantage of the economies of this higher voltage for fluorescent lighting. The

Figure 6—typical unit substation (across-page).

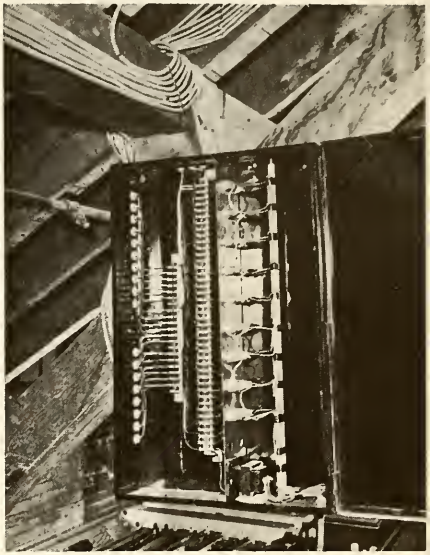


Figure 7—remote control relays grouped in a distribution panel having high and low voltage components.

reason for this is that no practical means of switch control was available to handle individual office circuits at higher voltages. The maximum rating of conventional flush switches is 250 volts and when these switches are used to control the inductive load of fluorescent lamp ballasts the current rating must be reduced by 50 percent. These restrictions are contained in the Underwriters' Laboratories Standards and in the National Electrical Code; they represent sound engineering practice. The introduction of the remote-control wiring system, with its approved use of solenoid operated relays for handling load current at 277 volts, now makes it possible to use 480Y/277-volt lighting in office buildings because the relay provides the required safe switching means for individual office circuits.

The remote-control system used for 480Y/277-volt lighting is identical with the system already in considerable use in residential occupancies. The relay which does the actual switching is operated from a low-voltage wall switch at 24 volts. Because only a momentary impulse of power is required to open or close the relay, a single-control power transformer serves for all of the switching on circuits in an area as large as an entire floor. The relays are generally mounted at the fixture or in such locations as will permit the shortest runs of the power wiring. Thus, the power wiring and conduit or other raceway material to the wall switch is eliminated. *(Figure 7 shows an installation of remote-control relays grouped at a distribution center.)*

Any apprehension which might accompany the adoption of higher voltage is of little moment here, because the public encounters only a switch operating at the safe value of 24 volts. Further, the design of fluorescent lampholders, unlike the familiar incandescent lamp socket with its exposed screw shell and center contact, has been standardized to eliminate exposed live contacts. These two factors—a low-voltage switch and a dead-front lampholder—are features which contribute to safety. The 480-volt circuits have for many years been common to power application so that distribution problems and standard apparatus for these voltages have been carefully worked out. A five-story, 180,000 square foot office building recently designed with 480Y/277-volt distribution showed savings of $30 per kva of installed electrical equipment and a net saving of 4 pounds of copper per kva. The total reduction in cost for the 480Y/277-volt system, compared to a 208Y/120-volt system, was $45,000. In this design, power was received at a unit substation at 13.8 kv and distributed first by busduct feeders and then by rigid conduit branch circuits, with remote-control relays for switching the individual lighting circuits. Provision of 120-volt power for convenience outlets was made on a basis of 1 watt/square foot from 480- to 120-volt dry-type transformers. Of the total cost reduction of the higher voltage system, 65 percent was in the substation and power equipment, and 35 percent in the wiring. Hence, with power supplied by the utility from a 480Y/277 network and no transformer required, a good saving would still exist.

No discussion on wiring systems would be complete if it did not make a plea for adequate wiring. The architect and the engineer under pressure to keep costs down are prone to recommend an electrical network for the commercial building which barely meets the power requirement for the initial occupants. Where the building will be known to have a definite life, as in the case of a temporary "tax payer," such recommendations are probably fair. But it is a gross disservice to the owner of any building to recommend an electrical system that does not recognize an increase in the use of electricity of at least the rate which has prevailed over the past two decades. The loss in rental for the time required to rewire an office may often exceed the initial cost of an adequate wiring system for that office.

Figure 1 (above)—one of two operating rooms in the Stillwater Municipal Hospital (Oklahoma) protected by standby circuits. Power for all essential lights in this 60-bed hospital is provided by the plant shown in Figure 2.

Figure 2 (left)—this 5000-watt unit is operated on city gas; when regular power fails, automatic control switches the load over to this plant. ***Photos: courtesy of D. W. Onan & Sons, Incorporated***

Standby Power Plants

BY I. J. CROWLEY*

We have become so dependent upon electric power that an interruption of even short duration may result in loss of production, property, and even human life. As the demand for emergency power has steadily increased since the end of World War II, the installation of standby power equipment has become an important consideration in the planning of hospitals, department stores, hotels, office buildings, institutions, airports, pumping stations, and—most recently—bomb shelters.

The principal factors which should be reviewed before specifying this type of equipment will be analyzed in the following paragraphs.

automatic vs. manually operated units. Where prompt restoration of power (within 15 seconds) is of paramount importance, only a fully automatic unit will satisfy this requirement. This type of plant is essential for hospitals that have not been provided with automatic emergency lights in the operating and delivery rooms. Fully automatic units also must be provided where operating personnel is not available at all times or where the personnel may be incapable of starting and operating generating equipment.

Where a power loss of short duration, say a matter of minutes, will not have serious consequences, a manually started unit will provide satisfactory protection—assuming, of course, that personnel familiar with the equipment is in constant attendance. The Greenwich Hospital, Greenwich, Connecticut, possesses a manually started 50-kw (62.5 kva) diesel-driven unit which has given efficient emergency service for more than four years. During this period, seven power failures of varying duration have occurred—one failure lasted 17 hours. The operating and delivery rooms are equipped with automatic, battery-operated lights; however, at no time have other locations within the hospital been without power longer than 33 seconds. This efficient record was possible because the hospital employs three eight-hour boiler-room shifts and because the standby unit was given a half-hour operating test each week. The engine-generator unit (*see Figure 3*) is installed in the boiler room of this hospital; the switchboard is located near the main distribution panel in a switchgear room adjoining the boiler room. When normal power fails, the operator starts the engine, then goes to the switchgear room and shifts a manually operated double-throw switch from the normal supply to the emergency unit. The foregoing not only describes what actions must be taken in the event of a power failure but also indicates that conditions should be ideal for the use of manually operated units in hospitals.

determining and planning the emergency load. The load to be carried by the emergency unit obivously establishes the size of the unit to be installed. The wiring layout of a building should be planned so that circuits carrying essential facilities can be segregated from those deemed nonessential. The pieces of equipment usually considered essential are: oil burners, elevators, fuel and water pumps, and lighting. The operation of all elevators need not be provided for if selector switches are installed which permit the operation of one elevator at a time on the emergency unit. This will permit the discharging of passengers from any elevator which may be stopped between floors. In the case of existing buildings, it may be less costly to provide an emergency unit of sufficient capacity to carry the entire load than to attempt to make the wiring changeover necessary to separate essential facilities.

types of generating equipment available. Emergency generators are commonly driven by diesel or gasoline engines, or by steam turbines. Engines burning natural gas, manufactured gas, butane or propane, are also available. The prime mover to be used will be determined by the prevailing conditions and the decision as to which type will give the better results. The majority of engineers now favor diesel-driven generator sets. Diesels start and come up to speed in not more than five seconds; carry their rated loads easily; and respond quickly to sudden shock loads because of their lugging ability. They are heavily constructed, simple in design, easy to maintain, and are not subject to the rigid regulations and codes which apply to the installation of gasoline engines.

Gasoline-driven sets are efficient and when properly maintained will give excellent service. High-test gasoline should not be used in a standby unit. Since the engine is not operated for days and, more frequently, weeks at a time, the gasoline evaporates from the carburetor, fuel pump, and fuel lines. Further, high-test gasoline leaves a gummy residue in the fuel pump and carburetor, which in time—2½ to 3 years from date of installation—will render these parts inoperative and make their replacement necessary. This difficulty can be overcome by using white gas in the unit. A gasoline engine cannot start as rapidly as a diesel because the evaporation previously referred to makes it necessary to lift fuel

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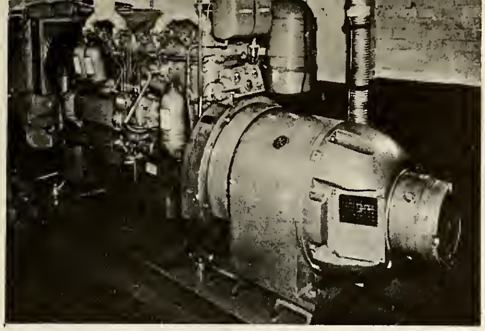
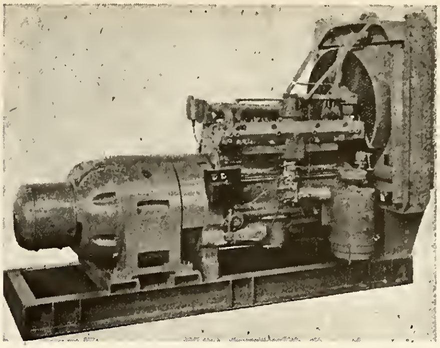
* *Sales Engineer, International Diesel Electric Company, Incorporated, Long Island City, New York.*





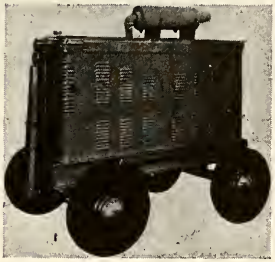


Figure 3 (above, left)—manually started 50 kw (62.5 kva) diesel-driven power plant located in the boiler room of the Greenwich Hospital, Greenwich, Connecticut.

Figure 4 (above)—small gravity tank mounted on gasoline engine (between engine and generator) provides quicker starting; tank capacity is limited to one quart, by National Board of Fire Underwriters.

Figure 5 (left)—small units, trailer-mounted, have advantages for localized emergencies.

Photos: courtesy of International Diesel Electric Co.

from the supply tank to the pump and carburetor before the engine will fire. This lifting has to be done at cranking speed. Diesel oil, however, will not evaporate and the injection pump delivers fuel to the injection nozzles on the very first turn of the starter.

To provide quicker starting, a small gravity tank may be mounted on gasoline engines *(see Figure 4)*. Fuel is pumped into this tank and then delivered to the carburetor. When the engine stops, this tank remains filled with fuel so that the engine will start promptly when next called upon. This small tank must be vented back to the main storage tank to avoid vapor lock; its capacity is limited to one quart by regulations of the National Board of Fire Underwriters.

Turbine-driven generators may be used where there is assurance of a continuing supply of high-pressure steam. They are quickly and automatically started by the use of a solenoid valve. Transferring the load back to the normal supply, however, must be done manually. No independent fuel supply or starting system is required.

Engines fueled with natural gas, manufactured gas, butane, or propane, assuming a nonfailing supply of fuel, will give satisfactory results.

Where a power failure can disrupt plant operations it is often advisable to have available a portable unit, mounted on a trailer. A 25-kw (31.25 kva) unit of this type is owned by the Kings County Lighting Company of Brooklyn, New York *(see Figure 5)*. When a failure occurs, this unit is towed to the point of failure and a portable cable run from the generator to the service.

generator ratings. An alternating current generator of standard manufacture is rated in kw (kilowatts) and in kva (kilovolt-amperes). The former rating indicates real power, or the generator capacity which is available for work. The latter rating indicates apparent power only. Standard ac generator ratings are based on a power factor of 80 percent: for example, 62.5 kva or 50 kw. It is advisable to give both ratings, as well as the power factor, in specifying generator capacities. Standard generator ratings are indicated in the table below:

kw	kva	kw	kva
5	6.25	75	93.8
7.5	9.4	100	125
10	12.5	125	156
15	18.7	150	187
20	25	175	219
25	31.3	200	250
30	37.5	250	312
40	50	300	375
50	62.5	350	438
60	75	400	500

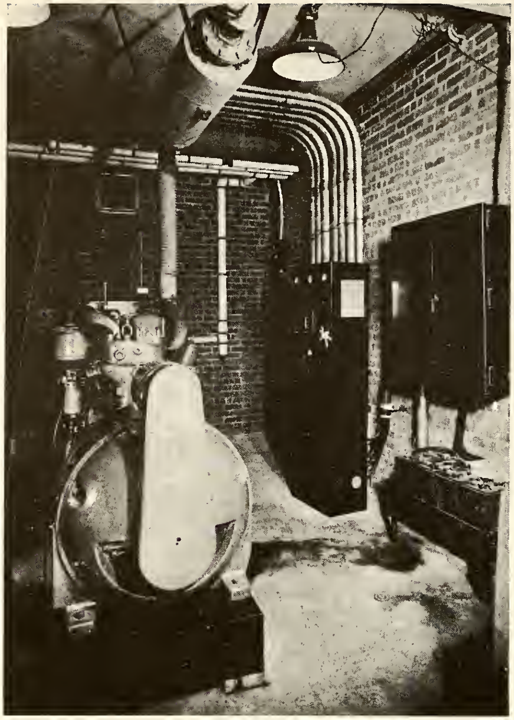
engine characteristics. The selection of an engine to drive a generator should be based upon obtaining, from the unit, a power supply of the same quality as that delivered by the public utility. A multicylinder engine should be provided —preferably one that does not have less than four cylinders. The speed at which the engine is to operate, of course, will have to be a synchronous speed—600, 720, 900, 1200, or 1800 rpm. Since standby units are used only occasionally, there should be no objection to operating at either 1200 or 1800 rpm. It should be noted that in *some* generator sizes the 1800 rpm generator is more expensive than the 1200 rpm generator, although the former is a four-pole machine and the latter a six-pole. This often results in a 1200 rpm unit costing less than an 1800 rpm unit due to the increase in the engine price being more than offset by the decrease in the generator price.

Engine accessories should include at least the following: air cleaner, fuel filter, lube oil filter, starting batteries with cables and electrolyte, trickle charger, safety alarms, flexible exhaust connection, and muffler.

Two methods of engine cooling are in general use. First is the conventional radiator and fan. Second, water from the normal supply is passed through the engine jackets, or through a heat exchanger, and off to waste. A heat exchanger should be used where raw water from the local supply might cause corrosion in the engine block.

Where water from the normal water supply is used for cooling, the rate of flow is regulated by a thermostatically controlled valve. This results in maintaining a given temperature regardless of load fluctuations or changes in ambient temperature. Where a heat exchanger is not used it is good practice to provide an expansion and mixing tank on the engine. Without such a tank, in the event of failure of the thermostatic valve, it is possible to seize the engine by a sudden inrush of cold water. (A 100 kw diesel unit equipped in this manner is shown *(see Figure 6)*.

When considering the possibility of bombing attacks, which could disrupt water supply, closed cooling systems are preferred. Where engine-room temperatures are high enough to prohibit the use of a radiator and fan, the radiator may be installed in an outside wall and a motor-driven fan mounted behind it. Where this system is not feasible, a method often referred to as "high-temperature cooling" may be used. The radiator and fan are eliminated and the



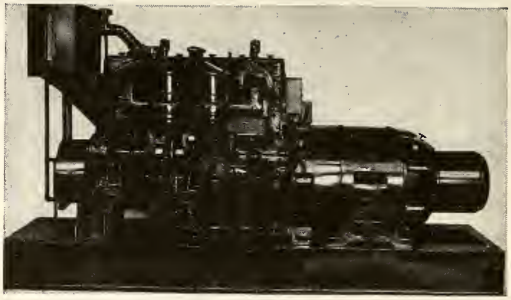


Figure 6 (above)—this diesel-driven unit, cooled by a local supply of water, has an expansion and mixing tank mounted on the engine to prevent the engine from being seized by a sudden inrush of cold water.

Figure 7 (left)—a free-standing switchboard and horizontal muffler above can be seen in this illustration.

Photos: courtesy of *International Diesel Electric* Co.

engine is operated at temperatures as high as 240 F. A steam separator is utilized and the hot water is returned to the suction side of the jacket water pump. The steam may be discharged to atmosphere, or may be condensed and returned to the separator. Where the steam is condensed, very little make-up water is required; if the steam is discharged to atmosphere, a reasonable supply of make-up water must be provided.

The conventional engine starting system comprises an electric motor with worm-gear drive and batteries. Criticisms of this system are based upon the limited life of batteries. Lead batteries carry guarantees of from 18 to 24 months and should be replaced at least every two years. This becomes an expensive item. Glass-jar or nickel-cadmium batteries, although initially higher in cost, will result in a saving over a period of years because their life is many times that of lead batteries.

The electric starter may be replaced by supplying a starting winding in the generator which is energized by batteries. This system is practical only in small generating sets. In larger units, the physical size of the generator and the battery capacity required become excessive.

The one system of starting which requires no batteries is compressed-air starting. Large diesel engines are universally started by this method. A compressor and air-starting tanks, with pipe connections to a starting valve in each cylinder head, are used. Air is admitted to the starting valves from a storage tank. A valve gear opens and closes the valves at the proper time and in correct sequence to keep the engine rotating until the fuel ignites and the engine starts to run under its own power. At this point the starting air is shut off. The opening and closing of the air supply is done manually; however, some progress has been made in the use of air-starting with automatic units.

Comparatively small diesel and gasoline engines are sometimes used in standby units. These engines are not equipped with air-starting valves in the cylinders. To use compressed air for starting these engines, an air motor is used in place of an electric motor. As in large diesels, a supply of compressed air must be provided. The initial cost is about four times that of the starting motor and battery system; however, the expense of battery charging and servicing is eliminated. It is predicted that air-starting will be increasingly favored. To bring the system into general use, positive controls must be designed which will automatically supply starting-air to the motor and shut it off when the engine is operating under its own power. At least two companies are studying this problem at the present time.

engine and generator assembly. The engine and generator shafts may be connected by means of a flexible coupling; or a flanged half-coupling mounted on the generator shaft may be bolted into the engine flywheel. Before connecting the engine and generator shafts, a responsible manufacturer will determine whether or not the new mass, the two shafts, will produce a critical at the operating speed. Should a critical result at or about the operating speed of the unit, a torsional vibration is set up and there is a good possibility that the shaft will break. To eliminate this hazard, an extensive mathematical procedure known as a torsional analysis is followed.

A standby unit is usually guaranteed for only one year. During the guarantee period an existing critical may not become apparent, due to the infrequent use of the unit. It is therefore important that specifications provide that the manufacturer must submit copies of a torsional analysis. When assembled on the base, the engine, generator, and accessories should be readily accessible for servicing or repairing.

switchgear. Switchboards may be free-standing, wall-mounted, or unit-mounted types. Because they are not affected by vibration and do not interfere with the circulation of air around the unit, the first two types are preferred. Instruments mounted on the board include the following: voltmeter, ammeter, frequency meter, voltage regulator, exciter field rheostat, circuit breaker or fuse block, and trickle charger. A typical free-standing board is shown (*see Figure 7 in right background*).

shop tests and acceptance. When the generating unit is complete, it should be given a full-load operating test at the plant of the manufacturer. This test should be witnessed by the principals or by the consulting engineers. Such tests not only demonstrate that the unit will carry its rated load but also insure that all accessories have been included. Should it not be convenient for the principals or engineers to be present at the test, an accredited testing or engineering firm may be delegated to perform this function.

installation. The installation, with particular reference to gasoline-driven units, should be made in strict conformance with the regulations of the National Board of Fire Underwriters, and local ordinances.

Fuel-supply tanks are to be buried under at least two feet of earth. The top of the tank must be below the bottom of the carburetor. Where units are to be installed in basements, the latter rule is difficult to comply with. In these cases, the tank may be buried beneath the engine-room floor if it is covered by four inches of reinforced concrete. The vent and fill lines must terminate outdoors. The fuel tank may be supplied with a remote-reading dial gage, if desired.

Exhaust lines preferably should be installed in a horizontal position. This is desirable because condensation in the line will collect in the muffler where it can be drained, or can be eliminated when the unit is operated. In cannot reach the interior of the engine, as happens when the muffler is installed in a vertical position. A horizontal exhaust line is shown (*see Figure 7*).

The exhaust tail-pipe should pass through an outside wall and be cut off at a 45-degree angle to prevent the entering of rainwater. Should the pipe pass through a combustible wall, local fire regulations will indicate the precautions to be taken. Exhaust lines may be discharged into existing stacks only with the approval of the authorities involved.

Batteries should not be installed on the unit. If so installed, they are subjected to the heat of the engine and the sealing compound may be dissolved. Also, acid may reach and damage the generator windings. It is best to provide a channel iron tray, or frame, which stands on the floor free of the unit. A battery charger mounted within the switchboard will simplify installation.

periodic tests. Standby plants should be given a load test once a week and be permitted to operate at least until the water temperature reaches the specified operating rate. Lubrication, fuel, water, and batteries should be checked as a part of the weekly test.

sample specification. Suggested specifications for a standby unit follow:

EMERGENCY GENERATING UNIT

general—The generating unit shall consist of a ——— engine, direct connected to a —— kw (—— kva), —— phase, 60 cycle, —— volt generator.

engine—The engine shall have at least —— cylinders and develop not less than —— hp at ——— rpm. The engine shall be equipped with the following:

oil bath air cleaner
fuel oil filter
lube oil filter
circulating water pump
—— cooling system

generator—The generator shall be rated —— kw (—— kva) at 80% power factor with exciter, meeting all A. I. E. E. and N. E. M. A. requirements.

switchboard—The switchboard shall be of the ————— dead-front type, containing the following instruments mounted and wired:

ammeter and ammeter switch
voltmeter, voltmeter switch
voltage regulator
exciter field rheostat
circuit breaker
frequency meter
necessary current and
potential transformers
trickle charger

accessories

batteries with electrolyte,
cables and battery tray
muffler flexible exhaust hose
vibration isolation material

assembly—The engine and generator shall be mounted on a structural steel base; the engine begin connected to the generator by means of a ————— coupling.

shop tests—The engine, generator, and all accessories shall be given a witnessed shop test at the plant of the manufacturer, at various loads and at full load. The manufacturer shall provide all facilities for testing at no additional cost. Copies of torsional analysis must be furnished.

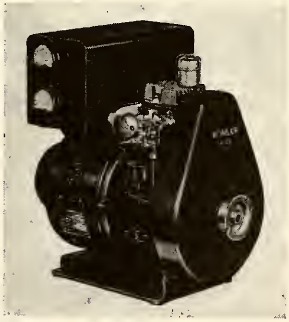
materials—All materials shall be new, unused, of recent manufacture and best suited for the application.

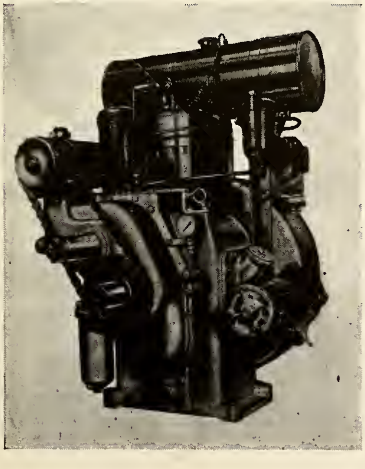
drawings—The manufacturer shall supply ——— copies of outline assembly and —— copies of wiring diagram. All piping and wiring connections shall be clearly indicated and sizes given.

warranty—The manufacturer shall warrant the entire equipment free of electrical or mechanical defects for a period of one year from date of shipment.

Figure 8 (right)—this 750-watt, 115-volt, ac, emergency unit has one cylinder and is air-cooled; gasoline operated, it starts and stops automatically.
Figure 9 (below)—a one-cylinder, air-cooled Armstrong-Siddeley diesel engine which develops 8 hp at 1200 rpm.

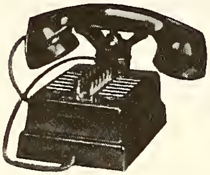
Photo: courtesy of Kohler Company
Photo: courtesy of Lister-Blackstone, Inc.





Intercommunications Systems for Commercial Buildings

BY O. L. ANGEVINE, JR.*



Above: this telephone master station may be used in a selective-ringing selective-talking system, or as a master in a school or auto court system. By turning handset cradle around, it can be wall mounted.

Below: available in desk and wall models, this telephone sub-station can also be used in a common-talking code ringing system.

Above: telephone for common-talking selective-ringing system. *All photos in this column: courtesy of Stromberg-Carlson Company*

Efficient intercommunication for commercial buildings may be provided today by any one of several methods represented by the products of at least 30 manufacturers in this country alone. There are telephone systems, amplified voice systems, various combinations of both, and occasionally intercommunication is incorporated in sound systems which also carry wired music and voice paging. Business organizations are just beginning to realize the many advantages of these tools, and as they will undoubtedly be used with increasing frequency in the future, it will be well to examine the different methods which have been developed so that the occupant may be provided with the most practical system for his particular needs. In the planning stages of commercial structures, architects must provide the necessary conduits, raceways, and feeders for installation during construction so that later defacing of interiors, exposed wiring, and high cost of future changes will be eliminated.

telephone systems

Basically, the telephone type of intercommunication is simply a private telephone system. The kind of equipment employed depends upon the number of stations, or, in telephone parlance, the number of "lines" involved. Large systems, containing more than 50 stations, are operated in a manner similar to that of a telephone company exchange. Some business houses buy their own equipment rather than leasing these facilities from the telephone company. In these circumstances, telephones on a private exchange cannot be connected to the telephone company's lines, and offices requiring outside communication must be provided with two phones. This type of system must have its own power supply; it frequently will consist of a battery and charging equipment which can provide power for service even if commercial power fails. A single pair of wires connects each telephone to the switchboard.

A more usual size of telephone intercommunicating system is one consisting of less than 25 stations; several systems of this type are available and all necessary equipment, except for the cable and power supply, is contained in the telephones themselves. Power may be supplied by dry cell batteries or a rectifilter operating from 110-volt a-c mains. The life expectancy of batteries in such service is well over a year.

The most flexible of the small systems is the full "selective-ringing selective-talking" type in which each telephone is provided with a number of push-buttons for station selection. When a button is pushed, it rings the designated station; when released, it stays partially depressed thereby operating a switch that connects the two stations for a private conversation. When the handset is restored to the cradle, the button automatically springs up and disconnects the line. More than one button may be pushed to set up a conference call; at the same time, however, other conversations may be going on between other stations. A multi-pair cable containing one pair of wires for each telephone in the system (and usually two additional pairs) must be run to each telephone. It is obvious that wiring, labor, and cable costs would quickly become excessive if such a system were to be used for a large number of stations. It is an economical system, however, for 16 to 20 lines, or less.

In many cases, such systems may be pyramided. In an industrial plant, for example, the production manager might have his system, the sales manager his system, the chief engineer his system, and so on. Likewise, from each of the executive's telephones a line can be run to other executives' offices. Sometimes a secretary's extension telephone may be provided with only one push-button—she can answer any call, but can ring only her boss.

**Former Chief Engineer, Sound Equipment Division, Stromberg-Carlson Company.*

In this article, the author deals principally with privately owned intercommunication systems and does not include a discussion of the many internal communication facilities provided by the telephone companies.

Above: this system is made for ultimate capacity of 30 to 50 lines. Any phone may call or be called by any other phone. As it is completely automatic, no operator is needed; simple dial eliminates digit dialing.

Photo: courtesy S. H. Couch Company, Inc.

If a cheaper system is necessary, and there is no objection to restricting the number of conversations to one at a time, a "common-talking selective-ringing" system may be used. In this system, anyone who lifts his receiver may hear any conversation that is going on. Ringing is made selective, however, by providing a number of push buttons, each of which rings one station.

Since multiple conversations occur less frequently than might be supposed on a small system, this method works very satisfactorily except when people sensitive to eavesdropping are concerned. Cabling is reduced to one wire for each telephone plus three common wires.

A still cheaper system employs a single push-button per phone for code ringing. For example, the head of a company might be called by one ring, the sales manager by two rings, the bookkeeper by one long and one short ring, and so on. Only four wires are required in the cable.

Another type of system, suitable for small schools, provides one master station with a number of buttons for selective ringing. Each of the other stations, however, has only one button which will ring the master. In order that one remote station may call another, it is necessary to call the master station and request that it ring the second station; however, this is not a disadvantage for schools where most calls are between office (master station) and classroom (remote station). This principle is also used in apartment house telephones where the master station is frequently incorporated into the design of the mailboxes. In this case cabling consists of one wire from the master to each telephone plus three common wires interconnecting all telephones. A variation of this system providing "selective-talking" and eliminating the party-line atmosphere meets the needs of small hotels and auto courts. An annunciator is added to the master station to indicate which station was called. This variation requires three wires to each telephone plus one common wire.

Sixteen to 50 line operations are handled by a special type of system. A central equipment similar to the 100 line dial switchboard is employed; however, with a fewer number of stations, it is possible to use a much smaller and simpler switchboard. In this scheme only two or three wires run from each telephone to the central equipment; the multipair cable required by the push button system is not necessary. Although some prefer the push button type system and are willing to pay a little more, the point at which the central equipment system becomes cheaper than the push button system is about 16 to 20 stations. This, of course, does not apply to a system where there is a large number of stations as a result of pyramiding small systems, since the cabling in a pyramided system does not require a pair running from each phone to every other phone in the system.

Telephone systems offer simplicity in wiring, reliability with little maintenance, and privacy in conversations. Although common-talking systems can have conversations interrupted by a third party coming in on the line, a click always announces that such an interruption has been made. Telephones are especially suited to offices, where it is desirable that visitors are not able to hear what is coming over the line.

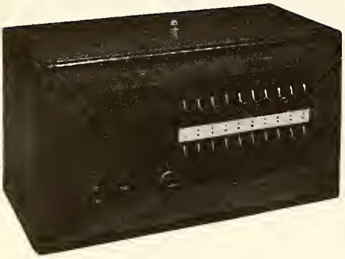
electronic intercommunication systems

The electronic intercommunication industry has grown remarkably during the last decade and its systems are now available for many functions and in a wide variety of styles. Two special advantages of electronic intercommunication are: 1) the ability to contact one or several parties instantly without waiting for the lifting of a hookswitch; 2) the ability to receive a message at whatever volume is required to exceed the background noise level or to be heard at a distance. These characteristics are of prime importance in controlling industrial processes such as the handling of materials, the operation of a shipping department, or prevent-

Below: executive stations for direct two-way conversation come with selective features for contacting up to 80 stations. Confidential earphone or handset can be provided for optional use. Individual volume controls can be regulated from a whisper to the requirements of the voice level.

Above: this staff station provides natural voice reproduction; "across the room reply" can be made without approaching the unit. Privacy and call-origination are also provided.

Both photos: courtesy of Executone Incorporated

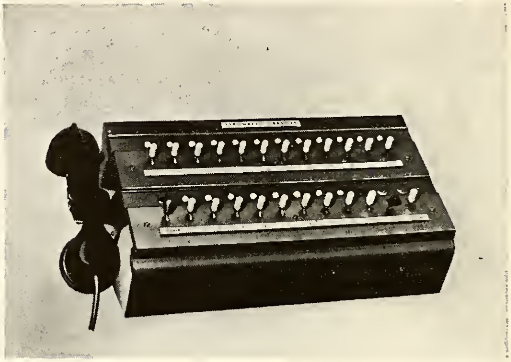


Above: an advantage of this model is that it need not require the use of a talk-listen key. A special, high fidelity microphone can be mounted on top of the cabinet; to converse with an individual at any other station, one flips the station selector key and talks back and forth without further use of keys.

Photo: courtesy of Bell Sound Systems, Incorporated

Below: 20-station nurses-call master station. The switchboard lamps come on when a button is pressed at the sub-station. By operating a switch under the light, they go out when the call is answered. A similar unit can be added to increase station capacity.

Photo: courtesy of Stromberg-Carlson Company



ing operational failures which could shut down an entire plant. At low volume, amplified voice systems are in common use in general and private offices, often using bell or light signalling plus earphone or telephone type handsets. A thorough knowledge of these systems is necessary so that the client may be provided with the one best suited to his needs.

In the basic amplified voice system, each master station contains a loudspeaker—which also serves as a microphone—station selection switches to call a number of other stations, and a vacuum tube amplifier. The equivalent of the selective-ringing selective-talking telephone system in amplified voice equipment is one in which each unit is a master station. By pressing a talk-listen bar or switch, the first party can speak and be heard by a second party. In order to reply, most systems require that the called party operate a switch to connect him with the caller; he must then operate his talk-listen key when he wishes to talk. Systems are available for use at low volume, however, which eliminate the talk-listen key; likewise, some systems are wired so that the called station is operated like a sub-station.

Sub-stations (remote or staff stations) can be used with any combination of masters or other sub-stations. These stations, however, can call only the master to which they are connected. Once a conversation is established, the person at the sub-station does not have to use a talk-listen key and may even answer a call from another part of the room provided that his voice will be louder at the station than any other noise in the room. As a master can listen in on a sub-station, where privacy is desired a switch can be provided at the sub-station. Some manufacturers provide a warning light on the sub-station showing when the line is open, thus retaining the advantage of across-the-room reply.

Usually it is possible to interconnect other master stations or sub-stations to one master, although some manufacturers' equipment, designed only for master-to-master use, does not allow mixing. When one sub-station is similarly connected to two masters, it is necessary to use a sub-station with a cut-off key (interruption bar) so that one master station can be disconnected when the sub-station is engaged in conversation with the other master; thus the possibility of double amplification is prevented. With additional wiring, the interruption bar can be a relay in the sub-station controlled by the station selector switch at either master, thereby retaining the sub-stations ability to receive a reply from across the room.

One system is available which combines the talk-listen switch with the station selector key and uses only one amplifier for a six station system, yet each station is a master station and can call every other station.

Cabling required for master-to-master operation is one pair of conductors for each station in the system. The cabling needed from the master to the sub-station is one pair of conductors plus an additional shield which is used as the third conductor. Shielding means that a metallic braid is woven over the wires of a pair of conductors. An additional wire is used when a warning light is employed at the sub-station.

As in the telephone system, it is possible to pyramid a number of few-station systems into one large network. Cabling costs can be reduced by using a common-talking wiring in which all stations hear any conversation conducted on the system. This method is undesirable for office use, however, but is sometimes demanded in intercommunication systems for controlling machine operations so that everyone may know what orders are being given. Sometimes paging systems are adapted to this purpose, as, for example, in controlling the operations of a rolling mill where several stations may have to advise all operators simultaneously on the progress of a roll. Such systems are high-powered.

It is possible to connect either amplified voice or selective-talking interior telephone intercommunication systems to a voice paging system. In this case, one of the buttons is marked paging, and operating it will permit paging of an entire plant from one station. The called person may go to the nearest sub-station and call the station originating the page in the normal manner for placing a private call. Sometimes this procedure is not desirable as it allows a large number of people to page without control and without choosing the best voices for paging. It is usually better to provide a separate paging system with a microphone designed for high-level paging and with a selected operator.

mixed systems

The foregoing paragraph suggests that it should be possible to mix amplified voice and telephone type systems. In some cases, the amplified voice system achieves telephone privacy by providing a telephone receiver which can be lifted up at the user's option so that the incoming message is brought quietly to his ear rather than coming over the loudspeaker.

A better marriage of the two systems is the scheme which employs the telephone type handset for an office end of an intercommunicating system and provides electronic amplification for stock rooms, warehouses, and so forth. Such systems give privacy at the office end yet deliver a high volume for a large stock room. If, in addition, the stock room and production areas are wired as sub-stations, it is not necessary for the stock clerk to operate a talk-listen key and he can answer from any point in the room.

Similar systems designed for use in garages, or in hospitals for nurses call, may be given names which suggest their application. The nurses call system is tied into the familiar push-button at the patient's bedside, corridor lights over the patient's door, and at the nurses' stations. With an intercommunicating system, however, the nurse need not go to the patient's room to answer, but carries on a two-way conversation with the patient. A telephone handset is provided at the nurses station and a quiet loudspeaker in the patient's bedroom.

School sound systems which are used to distribute radio or phonograph programs to selected classrooms are often equipped with an intercommunication channel. This makes it possible to hold two-way conversations between the classroom and the central equipment, which is usually located somewhere near the school office. Many schools use such a system in place of telephones in the classrooms. Other schools use a common-talking or selective-talking telephone intercom to their classrooms instead of leasing phones from the telephone company connected to the school switchboard. In such cases, it is frequently possible to use the wiring of the school sound system for the telephones. It is desirable to plan this procedure at the time the wiring is installed, as it may require somewhat different wiring than would be installed for the school sound system alone.

survey and maintenance

To provide the client adequately and at the same time insure his not being overloaded with unnecessary masters or sub-stations, it is recommended that a communication survey chart be prepared to determine his intercom needs. Manufacturers providing complete service for their clients are able to prepare these surveys with competence. Another important consideration in the selection of any intercommunication equipment is to ascertain how it will be serviced when a breakdown occurs. Some manufacturers require the equipment to be returned to the factory for repair, while others provide on premises service.

Left: this 24-circuit master station has an optional handset for privacy of incoming conversations; no operation of controls is required; busy signal insures uninterrupted conversations.
Photo: courtesy of Rauland-Borg Corporation

Below: this sub-unit is wired back to a central automatic exchange. Up to 20 points can have instant contact with each other with a simple flick of a switch; talking can be done by loudspeaker or telephone instrument at any point. Conversations can take place at distances up to 30 feet from unit.
Photo: courtesy of Hadley Sound Equipments

Patient-Nurse Two-Way Communication

BY L. T. CHANDLER*

In the past, nearly all hospitals have employed a lamp-signaling system from patient to nurse which, briefly, consists of a calling button with cord at the patient's bedside, a corridor lamp over each room entrance, a pilot lamp in the duty rooms, and a lamp annunciator in the nurses' station. When the patient presses his calling button, the lamps in the corridor, in the utility, and in the nurses' station (indicating the room calling) are lit and remain lit until the bedside calling button is reset. Most systems have a buzzer associated with the utility station and an annunciator which sounds momentarily when the button is pressed, so that the nurse will know that a room is calling even though she may not be facing the lamps at that moment. This system necessitates the nurse going to the bedside of the patient who is calling to determine his needs. Many times the nature of the need is such that the nurse must then go to the duty room or diet kitchen for additional equipment. It has been recognized recently that a communicating system could be made that would permit a two-way conversation between patient and nurse, not only saving the nursing staff many steps, but also giving the patient quicker service and assurance, through the direct conversation with the nurse, that the call will be attended.

The continued shortage of nurses justifies the use of any system which will help the nurse in caring for more patients without reducing nursing standards. A patient-and-nurse two-way communication system can contribute greatly to the efficiency of patient care; however, the following should be carefully considered by those responsible for specifying such a system.

requirements of system

Certain desirable features of the straight visual system as used in the past should be retained. These are:

(a) The use of corridor dome lights over room entrances, since there will be cases—especially in the smaller hospitals—where the nurse leaves the nurses' station to answer a patient's call and in the interim misses another call. The corridor lamp will then warn the nurse to go to the second room before returning to her station.

(b) Easy removal of any patient's calling-button cord set from the system, so that the button and cord may be cleaned periodically or, if necessary, repaired or replaced after long usage. During removal, a means should be provided to cancel the automatic disconnect feature (described below) so that, when the new or cleaned cord set is installed, the automatic disconnect feature is immediately and automatically restored.

(c) The use of the automatic disconnect feature in the patient's calling button and cord: In the event the patient accidently pulls his calling-button cord from the wall or if the cord plug is not properly engaged in its receptacle, all lamps in the system associated with that room will be lit and the buzzers in the utility room and nurses' station will sound continuously, thereby signifying to the nurse which button is inoperative.

(d) The use of a pilot lamp and buzzer in each duty station and diet kitchen, or at any point where it is desirable to notify a nurse that there is a call registered at the master station. This is especially desirable for night duty where the nursing staff is reduced to a minimum and it is impossible to have a nurse continuously at the nurses' station (where the master station is located).

(e) Emergency calls from rooms where no microphone speaker is desired (toilets, bathrooms, and operating rooms) should register on a small lamp annunciator having a continuous sounding buzzer or bell in the nurses' station. It is usually not practical or economical to have these calls come in on the nurses' master station which handles all calls from the rooms equipped with microphone speakers.

All equipment should be designed to have a pleasing appearance, with minimum space requirements. This is especially true of the equipment used in the patient's rooms, since the combination speaker-microphone and calling cord receptacle must be mounted in a prominent place on the wall over the bed. The use of a single stainless-steel or sprayed satin-aluminum plate for this equipment is desirable from appearance and utility considerations, as it will match other electrical devices in the room, such as switch and duplex receptacle plates, etc. The patient's room station illustrated (*Figure 1*) is the same size as a standard 3-gang electrical face plate; measures only 6¼″ wide and 4½″ high; and requires a standard 3-gang outlet box 2¼″ deep.

Since the equipment of the system requires 24-hour use because of its important function, all parts should be made of the highest quality material and extremely rugged. For example, the switches on the master station (*Figure 2*) receive hard usage and should be of a telephone-cam-key construction with silver contacts. These should be mounted in a vertical position so that dirt and dust cannot easily lodge there and cause faulty operation. The calling button should be shock resistant; its electrical cord should have quality insulation with an outside covering of neoprene to assure long life and to remove the danger of electrical shock to the patient.

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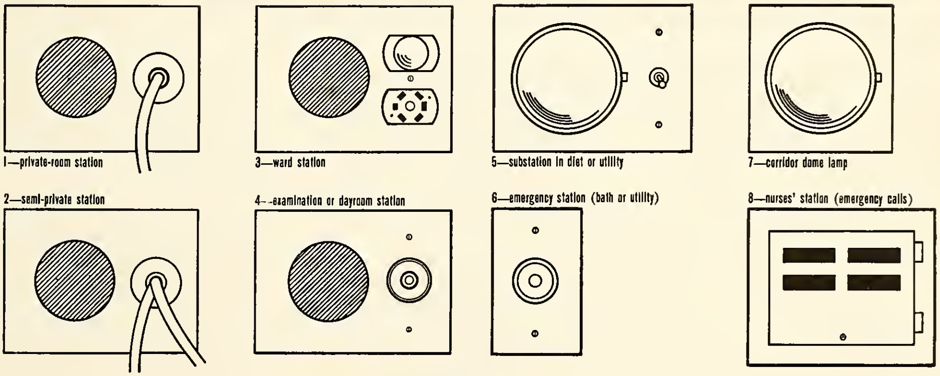
* *Supervisor, Sales Engineering, Edwards Company, Inc., Norwalk, Conn.*

Figure 1—patient initiates conversation by pressing call button (below, left). *Figure 2—master station combines built-in amplifier and double-throw cam keys to increase room station capacity and reduce size of cabinet* (below, right). *Figures 3 and 4* (center and bottom) *illustrate the eight stations of the system and a conventional conduit layout.*



1—private-room station

2—semi-private station

3—ward station

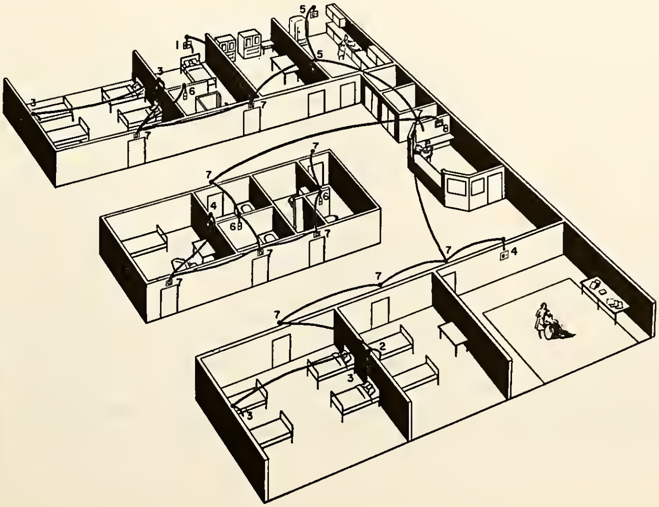
4—examination or dayroom station

5—substation in diet or utility

6—emergency station (bath or utility)

7—corridor dome lamp

8—nurses' station (emergency calls)



The system should be designed for minimum servicing and where replacements will eventually be needed, such as in the tubes of the amplifier, accessibility to those parts must be of prime consideration, to keep maintenance costs as low as possible. To insure continuous operation, the amplifier which is the heart of the system should be designed so that it can be completely removed and a new one installed in a few minutes time.

The electrical circuit and its components should be as simple as possible and designed so that the average hospital maintenance personnel may make repairs and replacements, thereby keeping maintenance costs comparable with those of the lamp-signal systems used in the past. For example, the complicated locking or sequence-type relays and other devices, which are difficult to adjust and maintain, should not be used. As is true for other hospital electrical equipment, the system should be manufactured by a company that is reliable and has a record of experience in signaling, backed up by a nationwide service organization with readily available parts and personnel for assistance when needed.

The equipment should be so designed that it can be easily and economically installed, as the cost to the hospital is the installation plus the maintenance expense. Use of electrical back boxes, where possible, is desirable for this reason.

The system should be able to transmit clearly the faintest voice from the patient and also transmit the voice of the nurse to the patient so that it may be clearly understood. The volume of the conversation should be such that it is not carried into the corridors or, where speakers are used in wards, be annoying to the other patients. It is desirable to have a 3-level volume key on the master station which a nurse may immediately adjust to take care of very weak or very loud voices and thereby assure a proper volume at all times.

Privacy of conversation between patient and visitors, without eavesdropping by the nurse at the master station, is a question of debate by hospital authorities. Some contend that the nurse has neither the inclination nor the time to eavesdrop. However, the system which will be described later is so arranged that the patient must first operate his calling button in order that the nurse may hear his (or the visitor's) voice —unless a monitoring feature is desired.

Most hospitals agree that monitoring of the patient's speaker by the nurse has doubtful value. The monitoring feature would mean that the nurse could call or listen into any room from the master station without the patient pressing the button. Although claims have been made of the nurse being able to listen in for patients' abnormal breathing, this is debatable. Also, this feature may create a tendency to neglect established routine visits to the patient by the nurse. If monitoring is possible, it would void the privacy advantage unless a cutoff switch is placed at the room speaker. This would increase the costs and permit the possibility of the patient's neglecting to throw the switch back to its normal operating position.

Since the spaces assigned as nurses' stations are usually open to the corridor and not behind closed doors, the master station should be equipped with a handset so that the patient's needs are confidential to the nurse. This gives the patient more confidence in the use of this type system and is an advantage over the loud-speaker type of master station. Furthermore, a lower volume booster is required of the handset type, keeping distortion to a minimum and permitting greater sensitivity in picking up the patient's voice. The handset also permits the nurse to use a normal speaking voice and prevents background noises and conversations in the nurses' station from being broadcast into the patient's room.

It is very important that the system assures that all calls are indicated at the master station and that it is not possible for a call to be intentionally or accidentally canceled by the nurse at the master station. Resetting should therefore be done only at the patient's bedside. This is accomplished by having the calling button of the locking type, with a reset means in the button. The reset device in the button should not only be designed so that a patient can easily reset the button when requested to do so by the nurse, but also not be accidentally reset at any time.

In order to keep the system an efficient and easy-to-operate device, it must perform only the service for which it is intended. Trying to use or design the system for such functions as public address, intercom throughout the building, piping music, paging doctors, fire alarm, etc., destroys the efficiency of performing its prime purpose with generally disappointing results.

how the system operates

When a patient wants assistance, he presses his calling button *(Figure 1)* which causes a lamp to be lit and remain lit in the dome light over the room entrance, in the pilot light in duty, work room, or diet kitchen, and the associated pilot light on the nurses' master station. The buzzer in the utility station and in the nurses' station sounds momentarily. The nurse at the master station picks up the handset, *(Figure 2)* throws the cam key opposite the lit pilot lamp and, using the talk-listen key, converses with the patient. At the end of the conversation, the nurse requests the patient to reset his button, which extinguishes all associated lamps. The nurse flips that room station back to normal and is now ready to answer the next call. The system is so designed that in the event the patient does not receive immediate attention, he may repeatedly press his calling button which momentarily operates the buzzers in the system and flashes all associated lamps mentioned above.

proper placing of equipment

The microphone-speaker and calling button receptacle combination should be installed on the wall at the head of the patient's bed. The system is designed so that the patient need not face the microphone-

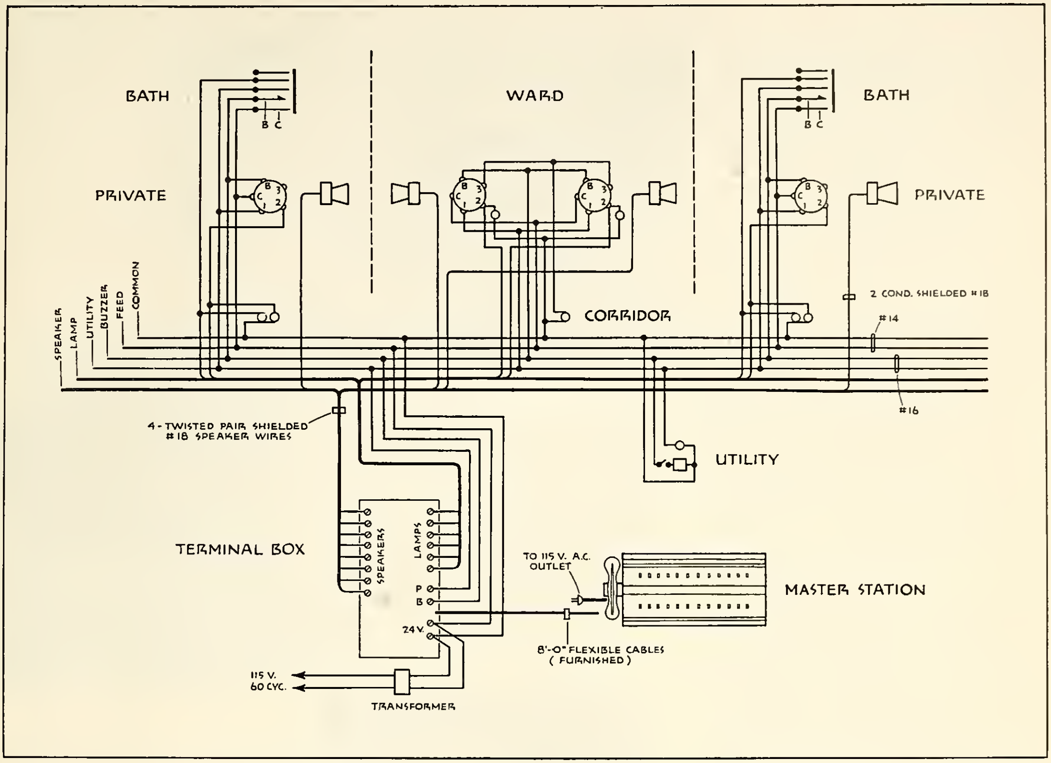


Figure 5—typical wiring diagram indicates number of wires and sizes required. Speaker and signal wires can be run in same conduit.

speaker during conversation. The calling cord which plugs into its receptacle (which is in the same face plate as the microphone-speaker) is 6′ in length. In semi-private rooms and wards, it is often most economical to use only one speaker between each pair of beds and a double calling cord which has only one plug and receptacle.

The master station can be installed on any convenient desk space in the nurses' station. Although the unit is portable, it is equipped with cables approximately 9′ long. These cables end in a terminal box, usually mounted in one of the walls. Sometimes certain locations for the terminal box are more advantageous from the electrical contractor's viewpoint and this, therefore, often determines the location of the master station and the desk on which it is to be mounted.

wiring requirements and power supply

Most systems permit the lamp, audible signal, and speaker wires to be run in the same conduit. However, this should always be checked with the manufacturers whose equipment is to be specified. Installation costs are naturally higher for those systems that are not designed to permit the one-conduit layout. The speaker wires should be shielded, twisted, pair No. 18 or larger. The signal wires should be No. 16 and the common feed wires running from the transformer secondary should be No. 14.

The eight stations of the system and a conventional conduit layout are shown (*Figures 3 and 4*). Conduit layout, of course, will be dependent on the type of construction used for the particular hospital. The wire sizes and number required are shown in the wiring diagram (*Figure 5*).

The system operates from the 24-volt secondary of a N.E.M.A. Standard heavy-duty signaling type of suitable capacity to light at least one quarter of the lamps on the system simultaneously.

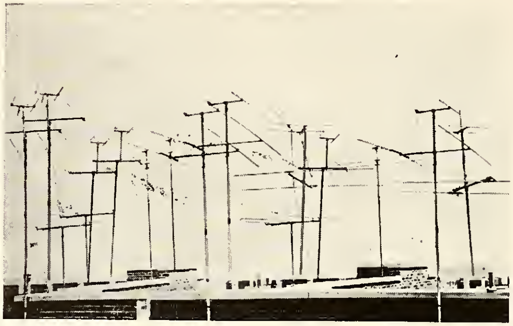
Television Antenna Systems for Multiple Dwellings

BY IRA KAMEN*

Television facilities for multiple dwellings deserve the same care and consideration during construction that are given to plumbing, heating, and ventilation. Installation of these important facilities after construction has been completed often results in more expensive and less satisfactory systems, with exposed wiring and equipment placed in undesirable locations. It is anticipated that built-in and portable antennas will never solve the television reception problem in multiple dwellings. This conclusion is based on the fundamental phenomena in physics that television waves, like light waves, will not bend, nor will they penetrate structural steel, metal lath, copper flashing, and so on; in addition, they will be attenuated by dielectric materials such as brick, stone, mortar, and others. An increase in power on present television channels is not practical and would result in interference with neighboring stations in nearby cities; furthermore, an increase in power would not solve the multiple reflection problem as the ratio of the desired signal, with respect to its reflections, would remain the same.

Figure 1 pictures a familiar sight in urban areas where a building, marred by a mass of unsightly, troublesome, and dangerous individual antennas, is also defaced by exposed lead-in wiring running along its walls. Installation of individual antennas, in addition to ruining the appearance of a building, often develops continuous and expensive maintenance problems, as these external antenna installations are not performed by trained mechanics but by those who are relatively unskilled in the mechanical arts, in comparison with trained electricians.

Contrast the rooftop view in Figure 1 with the permanently installed television master antenna system shown in Figure 2. In the latter, the tenants of a newly constructed apartment house are served from one neatly installed antenna per TV station, with concealed wiring to outlets in each living room, ready for plug connection of standard television receivers. It seems paradoxical to set up engineering specifications for power, lighting, elevators, and bell systems, and then allow the building to be torn to pieces by countenancing uncontrolled television installations.



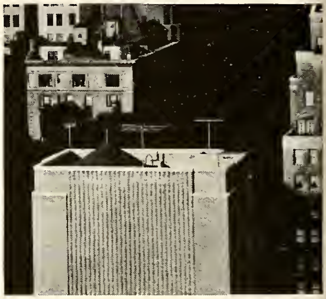
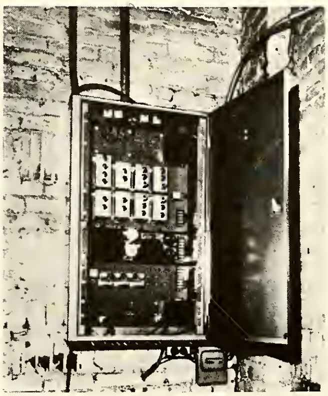


Figure 1, above: these familiar installations not only have a ludicrous and unattractive appearance, but also they frequently lead to serious maintenance problems.

Figure 2, right: the master antenna system on this apartment house tower serves all of the tenants in the entire building.

Figure 3, below: antenna booster amplifier rack containing one booster amplifier for each television channel plus FM and AM amplifier unit with booster supply.



A television master antenna system must provide performance in accordance with the following specifications:

1. Signal level at all television outlets shall be not less than 1000 microvolts on all television channels, which is a 100 percent safety factor over the minimum signal level specified by the Federal Communications Commission for stable television reception. A 100 percent safety factor is absolutely necessary to assure the longevity of the installation as the general aging of cables, contacts, and so forth, over a period of five or six years will tend to decrease the television signals available over coaxial cables.

2. Reflections induced into the television antenna on each television channel shall be such that they do not mar the picture to an objectionable degree from the normal viewing distance.

3. Television pictures on all channels shall be of a signal to noise level whereby the noise cannot be seen in the picture background from the normal viewing distance.

The following are general equipment and installation specifications (see Fig-

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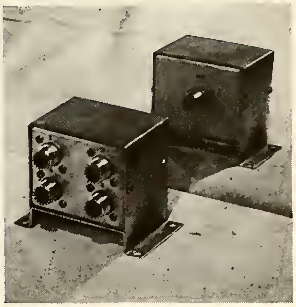
[*] *Television Consultant, New York, N. Y.*



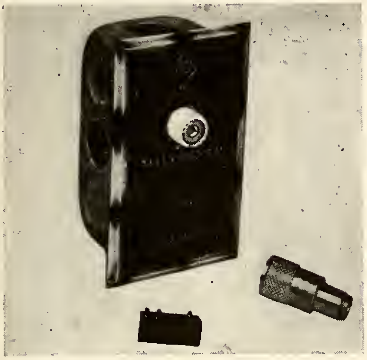
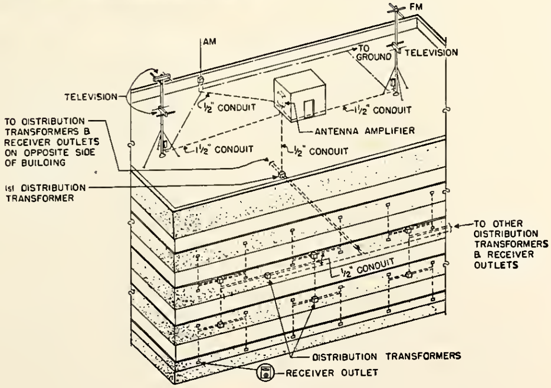


Figure 4, above: four-to-one distribution transformer distributes signals from output of amplifier to apartment risers. With separation of transmission lines, a short in one will not cause a failure of the entire system. Not all systems, however, are of the distribution transformer type.

Figure 5, left: receiver outlets when properly located eliminate exposed wiring.

Figure 6, below: this diagram shows the relationship of the various integral pieces of equipment which make up a television master antenna system.


FM
AM
TO GROUND
TELEVISION
TELEVISION
½" CONDUIT
1½" CONDUIT
TO DISTRIBUTION TRANSFORMERS & RECEIVER OUTLETS ON OPPOSITE SIDE OF BUILDING
ANTENNA AMPLIFIER
1½" CONDUIT
½" CONDUIT
1st DISTRIBUTION TRANSFORMER
TO OTHER DISTRIBUTION TRANSFORMERS & RECEIVER OUTLETS
½" CONDUIT
DISTRIBUTION TRANSFORMERS
RECEIVER OUTLET

ure 6 for approximate locations in a typical building):

Antenna: The television antenna shall be designed to match coaxial cable transmission line and be supported by a metal mast which is grounded to the nearest suitable ground for lightning protection. The antennas shall be custom built for each television channel and shall have connection facilities whereby it is possible to seal hermetically the ends of the coaxial transmission line which is used to feed the antenna signals to the antenna amplifier. All antennas shall be mounted to a structural member such as a roof joist or equally substantial foundation. Guy wires should be used where the antenna mast is higher than five feet.

Antenna Amplifier: The antenna amplifier should be located in a weatherproof structure such as a pent house, fan room, service hall, or basement. The amplifier operates on a 105 to 125 volts, 50-60 cycle alternating current. An a-c outlet fused for 15 amperes should be furnished at this location. The a-c outlet should have facilities for connection of soldering iron, and test equipment, as may be necessary, to maintain the installation. The amplifier is designed for continuous operation and, therefore, automatic control clocks are not necessary. The power consumption of the antenna amplifier does not exceed 180 watts.

Distribution Transformer: This piece of equipment will isolate the transmission lines from each other. A short in any one transmission line will affect only the number of outlets on the specific line which is shorted. The level in the outlets on those lines which are not shorted will remain at approximately their normal operating level.

Receiver Outlet: The television receiver outlet plate mounts on a single gang plate designed to fit the standard single gang outlet box. The single gang outlet box shall be 4" x 4" and have a depth, when used with a standard single gang collar, of not less than 2⅜".

The manufacturer, or distributor, of master antenna systems always has the responsibility of making the necessary engineering surveys to locate the television antennas, provide intermittent supervision as necessary for the electrical contractor, and make final test adjustments of the system. The test and adjustment of systems at this stage of television are too complex to be assigned to any but television engineering personnel; therefore, in the preparation of specifications for an electrical contractor, it is necessary to isolate this responsibility.

While Figure 6 may be used for engineering guidance on antenna system layouts, it is most essential that the architect make use of the manufacturer's representatives (who are normally the local distributors' engineers) for guidance in the preparation of specifications and layouts, as optimum operation can only be assured when the system is custom fitted to the specific building.

To date, the television industry (the Television Broadcasters Association and the Radio Manufacturers Association) has only specified and recommended in its engineering bulletins amplified types of antenna systems. As it is necessary to amplify before dividing signals, it may be said that permanent master antenna system installations which guarantee the performance in accordance with the standards outlined in this article and as established by the industry, can only be realized through the application of an amplified type system.

Minimum Elevator Specifications

BY PERLEY M. CLARK*

Elevator specifications, with drawings, serve two important purposes. 1) They indicate the type of elevator equipment needed to handle properly a building's vertical transportation requirements. 2) They provide each manufacturer with sufficient data to prepare an accurate bid; a bid as free as possible from future extras, and one that can easily be compared with those submitted by other manufacturers. This article is concerned mostly with the latter purpose. Its principal attention is directed to the data that must *be included in the minimum elevator specifications to prepare a complete, accurate bid. The data sheets of six prominent elevator manufacturers have been studied, and it was noted that although they varied somewhat in arrangement and in the amount of detail, all were found to agree on the minimum information needed.*

Preliminary Information

As soon as the architect determines that there will be an elevator in his building, he should call in a qualified consulting engineer who has had ample elevator experience, or a competent representative of an elevator manufacturer. The representative can make constructive recommendations regarding load, speed, and number of elevators, if these decisions have not already been made. Knowing the lifting capacity and speed desired, he can furnish space requirements, overhead reactions, electric power requirements, and other pertinent data. This information should be of such a nature that all manufacturers of comparable equipment will be able to install similar elevators under the same conditions. A reliable representative will not give information that will tend to restrict the bidding to one company.

The architect can now draw the basic features of the elevator installation on his plans. Most manufacturers can furnish typical layouts that contain much of the preliminary information required. Plans should include location, size, and type of door openings, location of guide rails, location of steel, car platform size, dimensions of the hoistway, and the hoistway wall construction. Sections should indicate the pit depth, floor height, location of steel, and the vertical distance between building members to be used for rail supports. The vertical distance between rail supports is important, as intermediate supports or guide rail backing will be required if the distance is too great. It is better to omit the exact elevation of the machine room floor, the precise location of reactions, and the specific size of the machine room, until the elevator contract has been awarded. These items may vary with different manufacturers.

The elevator contractor will demand that he be given a legal hoistway, pit, and machine room in which to install the elevator equipment. Therefore, the drawings must be checked against local building codes and regulations. Unusual site conditions, such as a water problem necessitating extensive waterproofing in the pit, must be considered.

It is not desirable to use descriptions or trade names that apply to one manufacturer alone. Use only the definitions given in the American Standard Safety Code For Elevators, Dumbwaiters, and Escalators (A.S.E. Code). This code is published by the American Society of Mechanical Engineers and is approved by the Bureau of Standards. Special requirements, if not completely described in these definitions, can usually be given a brief description without having to resort to the use of trade names.

An elevator specification that is too brief is misleading and tends to cause prices to be submitted on different bases. Those bids are difficult, if not impossible, to compare. Lengthy specifications may confuse the estimator and lead to misunderstandings or to long lists of exceptions when bids are submitted. Occasionally, longer and more detailed specifications are required. If so, they should be prefaced with a summary based on the minimum specifications. The minimum specifications contain the least amount of information required to make a proper bid.

Basic Data

The estimator will first look for the name and address of the building in which the elevator is to be installed, the name of the owner, and the name of the architect. He must know the type of occupancy, to whom the bid must be submitted, the exact date the bid is required, and whether a firm price or a budget estimate is desired.

**Application Engineer, Otis Elevator Company*

Most of this information will appear on the title page of the specifications or on the request for bids.

The elevator specification section (which should be included in the index) frequently begins with reference to General Conditions, a list of Codes to be complied with, and Bond and Insurance provisions. A paragraph covering the work to be done by contractors other than the elevator contractor should follow. Example:

> WORK BY OTHERS: Others to provide pit, elevator hoistway, machine room including floor, supports for guide rails and machine beams, necessary feeder wires to controller with fused outcut switch in the machine room, light outlet at center of hoistway, and current supply for starting, testing, and adjusting, all in accordance with local codes and regulations.

Minimum Elevator Specifications

After each of the following items there are blank spaces to be filled in for each elevator or each group of elevators having the same characteristics. The comments, after each item, are not part of the specification, but serve as a check list for the specification writer.

1. *Number of Elevators* ....
   Specify total number of elevators in building.
2. *Types of Elevators* ....
   Type of Machine ....
   Specify whether elevators are passenger or freight type. If there are different types, specify total number of each. Also specify whether elevator machine is a Geared or Gearless-traction machine. A rough rule is that Geared-traction machines can be specified for car speeds up to 300 f.p.m. For car speeds of 400 f.p.m. and over, specify Gearless-traction machines.
3. *Load (Capacities) .... Pounds.*
   Specify load in pounds that each elevator will be required to lift. Load for passenger elevators is determined by car platform size in accordance of local or A.S.E. Code. Load of each freight elevator may be controlled by local codes, but is usually determined by the type of material to be handled. If a freight elevator is to carry concentrated loads, such as industrial trucks, it should be mentioned, as the cars will then require extra heavy car platforms, car frames, and safeties. If, during loading operations, a freight elevator must support a static load greater than the lifting load, as when loading with industrial trucks, specify total amount of additional static load that the elevator equipment will be required to support during loading but will not be required to lift.
4. *Car Speed .... Feet Per Minute*
   Specify car speed on the basis of the load, number of floors to travel, height of building, traffic to handle, etc. For passenger elevators car speed should be determined by a consulting engineer or competent representative of elevator manufacturer on the basis of a building analysis. Do not hesitate to ask for assistance in solving this problem. A building analysis should *always* be made for large buildings. Car speed determines pit depth and overhead heights as well as the traffic handling capacity of the elevator equipment; therefore, any subsequent change in car speed can require changes in building plans. For freight elevators, specify highest economical speed for load according to best advice obtained from an elevator manufacturer's representative. For any given load an increase in car speed means an increase in motor horsepower and possibly an increase in machine size, with corresponding increase in cost.
5. *Operation* ....
   Specify method of operation according to definitions given in A.S.E. Code. Stay away from trade names. A common error is simply to specify push-button operation. This could be any one of a number of types of operation such as selective collective automatic operation, single automatic operation, or various others. Be exact and specific.
6. *Control* ....
   Specify type of control in accordance with descriptions in A.S.E. Code. A rough rule for passenger elevators is to specify generator field control (1) for car switch operation with elevator car speeds of 151 f.p.m. and over, and (2) for any type of automatic operation with elevator speeds of 101 f.p.m. and over. Specify rheostat control for all car speeds less than these speeds. For freight elevators, specify control according to load and speed requirements. A good rule is to specify generator field control if leveling is required. Generator field control should always be specified when elevator motor horsepower is greater than 25 horsepower.
7. *Car Leveling Device* ....
   Specify when accurate stops are required with rheostat control. *Always* include leveling when generator field control is used. Some leveling systems will level but will not relevel to correct for rope stretch. This can be appreciable when freight elevators are loaded with heavy industrial trucks. Some systems will level only in one direction and will not return to floor level if the car should overtravel the floor. Some systems called "two-way leveling" will correct for overtravel as well as undertravel and will relevel.
8. *Travel (Rise) from ...... Floor to ...... Floor, a Distance of ...... Feet ...... Inches.*
   Designate the lowest floor that the elevator will travel to, the highest floor, and the vertical distance between the highest and lowest floor levels.
9. *Stops* ....
   Count one stop for each level the elevator will be required to serve. For example, if a freight elevator has a rear opening onto a trucking platform at a different level from the opening at the front of the hoistway, this is an additional stop.
10. *Openings* ....
    Give total number of openings (entrances) in each hoistway. The number of stops and number of openings will be the same if all the openings are at the front of the hoistway and specification should read "Openings (specify number) all at front of hoistway." If there are two or more openings at any one level (rear or side openings) the total number of openings will be greater than the number of stops, and specifications should read "Openings (specify number) at front of hoistway at

...... floors and (specify number) at rear (side) of hoistway at ...... floors." Floor plans should clearly indicate location of all openings.

11. *Machine Location* ....
    If elevator machine is located above, specify "overhead." This is normally the most desirable location. However, if the machine has to be placed below for some very special reason, specify exact location. Example: Machine location at basement floor at side (rear) adjacent to the hoistway on foundation by others.

12. *Machine Room Floor* ....
    When machines are located overhead, specify whether the machine room floor is to be a concrete slab by others, or grating by the elevator contractor. If the machine is located below, specify grating at level of overhead sheaves by elevator contractor, instead of machine room floor.

13. *Car Platform Size .... Feet .... Inches Postways by .... Feet .... Inches Front-to-back.*
    Specify car platform size according to building and code requirements. The car platform size is the major item in determining the elevator's traffic handling ability. Here again, do not hesitate to ask for assistance in solving this problem. Remember also that the postways dimension determines width of door opening. For freight elevators, the car platform size is determined by the type of materials to be handled and the method of loading and handling. It is imperative that the architect determine well in advance the size and type of hand or industrial trucks, pallets, skids, etc., which must be accommodated. A knowledge of these factors is absolutely necessary to a proper determination of the final platform size. They may also directly affect the load and speed. When determining the car size, make sure that sufficient space has been allowed for the car operator and freight handlers. If guide rails are located in corners of hoistways, "postways" dimension should be changed to read "width." The width is normally the dimension taken from left to right when standing in the corridor facing the main entrance of the elevator at the main floor.

14. *Car Enclosure (Cab)* ....
    Specify for passenger elevators "net cab value" in dollars or refer to some specific design by name, number, or other means of definite identification. As a matter of standard practice the cab value, when specified, will always include the car enclosure, car door(s) with hanger (or car gate), cutouts for fixtures, certificate frame, and light fixture. If handrails, forced ventilation, protective pads, natural metal entrance columns, natural metal kick plates or other car features are desired, they may also be provided for in the allowance. The competent representative will be glad to check that the cab value is high enough to cover adequately the cab design, fixtures, and extra features desired. For freight elevators a normal specification would read: "The car shall be enclosed on .... sides to a height of 6′-0″ with sheet steel. Perforated (or solid) panels shall be provided to extend above the top of the side enclosure. A perforated (or solid) metal top and light fixture shall be provided."

15. *Car Flooring* ....
    For passenger elevators state whether flooring is to be rubber tile, carpet, or hardwood. For freight elevators, state whether flooring is to be hardwood, steel diamond plate, magnesium diamond plate, or other material.

16. *Car Door (or Gate) ...... Type ...... Feet ...... Inches Wide by .... Feet .... Inches High*
    Specify car door type (single slide, two-speed, center opening, or two-speed center opening) and size of opening. For passenger elevators always specify a car door as wide as platform size and type of door will permit. If a gate is to be used on a car switch operation passenger elevator, specify a "collapsing (horizontal sliding) gate." Never specify a car gate when using automatic operation as most codes require car doors. For freight elevators specify either a "collapsing (horizontal sliding)" or a "vertical lift counter-balanced wood (or wire mesh) gate." The latter is the most desirable as it gives the greatest amount of clear door opening, and should always be used unless limited overhead clearance at top landing requires use of a collapsing gate.

17. *Hoistway Doors .... Type .... Feet .... Inches Wide by .... Feet .... Inches High*
    For passenger elevator, specify type of door (single swing, single slide, two-speed, center opening, or two-speed center opening) and give dimensions of opening. The width of opening is controlled by car platform postways dimension. Passenger doors are usually furnished complete with decorative finish and require no painting in field. For freight elevator, specify whether doors are to be horizontal slide, single or double swing, or vertical biparting counterbalanced type, and give width and height of the *clear* opening. Note that bucks and sills for passenger elevator doors are normally furnished by elevator contractor. However, for freight elevators, channel door bucks and sills are by others and should be noted in WORK BY OTHERS. Freight doors are normally furnished with prime coat of paint, finish coat to be applied by others in field (mention in WORK BY OTHERS).

18. *Car Door (or Gate) and Hoistway Door Operation* ....
    For elevators with swing or horizontal sliding hoistway doors, specify: (a) hoistway doors manually operated or self-closing; (b) car and hoistway doors power operated; or (c) car door power operated. Where power operators are used on horizontal sliding doors the architect should specify whether a "High," "Intermediate," or "Slow" speed operator, as there is considerable difference in speed of door operation and cost between the various types. Where hoistway doors are manually operated, specify "Bar Interlocks." Where hoistway doors are self-closing, specify "Door Closers and Interlocks." For freight elevators

equipped with vertical biparting doors and vertical lift wire mesh car gate, specify manual or power operation for door and/or gate.

19. *Signals* ....
Choose the signals desired from those applicable to the type of operation. Here is a check list of the signals normally available for the various types of operation: (a) *Automatic Operation*: in car—car position indicator. At landings—hall position indicators, miniature mechanical dials in push-button faceplates or "In Use" (or "Car Coming") lights. (b) *Car-Switch Operation*: in car—single (or up/down) indication annunciator. At landings—dial indicators, hall lanterns with (or without) gongs, and starter's panel at main floor. (c) *Signal Operation*: in car—car position indicator. At landings—hall position indicators, hall lanterns with (or without) gongs, various types of hall buttons, and starter's panel at the main floor.

If there are two or more elevators in one bank, some type of coordinating or supervisory system must be specified. Here again it is advisable to seek competent counsel.

20. *Painting* ....
It is customary to specify that all exposed metal installed by elevator contractor shall be painted "one coat by elevator contractor."

21. *Maintenance* ....
The usual specification requires that the elevator contractor shall furnish free service on the elevator installation for a period of three months.

22. *Power Supply* ....
Volts .... *Phase* ....
Cycles AC/DC
Specify voltage, etc., that the elevator equipment will operate on. This is important, as some buildings may generate their own power which may not be standard for the particular area. Also, some buildings furnish their own transformers to change the power company's voltage to a desired value. Thus the elevator contractor must be told the exact voltage and current characteristics of the power circuit on which his equipment is required to operate. These characteristics may differ considerably from those of the power company's distribution lines.

23. *Inspection Fees and Permits by* ....
Specify if inspection fees and permits are to be obtained and paid for by the elevator contractor or by others.

24. *Special Items:*
(a) If the new elevator is to be installed in an existing hoistway, specify that the elevator contractor is to remove, retain, and dispose of all old materials. However, if the hoistway doors are being replaced they must be removed by others and should be mentioned in WORK BY OTHERS. (b) If there is occupied space under the pit of the elevator, specify that the counterweight be equipped with a safety device. (c) If guide rail backing is necessary, specify whether it is to be furnished by elevator contractor or by others. (d) If a specific delivery or completion date is required or demanded as a condition of the contract, this should be prominently mentioned. (e) If telephones are to be installed specify exact type of fixture and location. It is normal for others to wire to a point near the vertical center of the hoistway. The elevator contractor installs the phone cabinet in the car, hangs and connects the traveling cable. Others furnish and connect the telephone instrument.

25. *Special Instructions to Bidders:*
The architect should conclude his minimum elevator specification with a brief summary of any special instruction to bidders. Very often it is to the architect and owner's interest to know whether or not certain modern improvements have been included. Specifications may conclude with such a statement:
"Bidders shall specify whether or not their bids include the following:
1. Roller or Slide Guides
2. Sound Insulation Under Machine
3. Sound Isolation Under Car Platform

Sample Minimum Specifications

The following is a sample minimum specification. It would normally be preceded by the information outlined under "Basic Data" and be concluded as suggested in Item 25 above.

1. *No. of Elevators:* 1
2. *Type of Elevator:* passenger—Geared-traction machine
3. *Load (Capacity):* 2500 pounds
4. *Car Speed:* 250 f.p.m.
5. *Operation:* selective collective automatic operation
6. *Control:* generator field control
7. *Car Leveling Device:* include two-way leveling
8. *Travel from* basement *floor to* 6th *floor, a distance* of 53'-6"
9. *Stops:* 7
10. *Openings:* 7 all at front of hoistway
11. *Machine Location:* overhead
12. *Machine Room Floor:* concrete slab by others
13. *Car Platform Size:* 7'-0" *postways x* 5'-0" *front-to-back*
14. *Car Enclosure (Cab):* $1000 net cab value
15. *Car Flooring:* rubber tile
16. *Car Door:* center opening *type*—3'-6" *wide* x 7'-0" *high*
17. *Hoistway Doors:* center opening *type*—3'-6" *wide* x 7'-0" *high*
18. *Car and Hoistway Door Operation:* power operated by intermediate speed operator
19. *Signals:* in car—car position indicator. At landing—miniature mechanical dials in push-button faceplates
20. *Painting:* exposed metal to be painted one coat by elevator contractor
21. *Maintenance:* 3 months
22. *Power Supply:* 208 *volts*, 3 *phase*, 60 *cycles, AC*
23. *Inspection Fees and Permits:* by elevator contractor

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